THE UNIVERSITY OF ALBERTA

PREDICTING BEEF CARCASS
CUTABILITY

by

© ROBERT JUDD BUNNAGE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA

FALL, 1970

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "Predicting Beef Carcass Cutability" submitted by Robert Judd Bunnage, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

An investigation was carried out to determine the relationship between certain carcass measurements and carcass cutability of beef cattle. Measurements were taken from 205 steer carcasses from two sources and 38 heifer carcasses.

Carcass grade was inversely related to cutability (the percent of the carcass which was saleable) in the steer carcasses, indicating that as grade improved cutability decreased. Grade was not significantly related to cutability in the heifer carcasses.

Hot carcass weight was not highly correlated to cutability in any group but was correlated to weight of carcass muscle. When used in equations to predict cutability, carcass weight reduced the standard error but its use was not without misgivings because of suspicion that large carcasses with minimum fat would be predicted erroneously.

Rib-eye area and kidney fat were not highly correlated to cutability. Both were more highly correlated with carcass variables indicating carcass size than they were with variables indicating carcass composition. When added to equations predicting cutability neither variable reduced the standard error of the estimates very much and in some cases, their addition increased the standard errors.

Average rib fat thickness was significantly correlated to cutability in all three groups and when used in equations to predict cutability, it accounted for most of the accountable variation, with the exception of equations including percent retail round. This measurement was easily obtainable and its inclusion resulted in the

best prediction equations developed in this research.

Percent retail round and dissected shank muscles were also used to predict cutability. The percent retail round more accurately predicted cutability, likely because it represented a larger portion of the carcass. Dissected shank muscle weight proved very useful, when combined with rib fat thickness, to predict cutability. It was highly correlated with carcass weight, rib-eye area and total muscle weight, indicating that it represented animal size, but it was also highly correlated with cutability. These two variables could be used quite confidently to predict cutability if it were not possible to dissect entire carcasses.

Carcass length, shank muscle:bone ratio and carcass muscle: bone ratio were studied but were of little additional value in predicting cutability.

This research showed that usually one could predict percent carcass muscle more accurately than cutability. This was probably due to the difficulty encountered when trying to leave the same thickness of fat on the retail cuts from different animals, a problem not encountered by total dissection. It was therefore suggested that prediction of carcass lean might be more meaningful than prediction of cutability.

ACKNOWLEDGEMENTS

I am grateful to Dr. L. W. McElroy, Chairman of the Department of Animal Science, for allowing me the use of the department facilities and for providing the necessary beef carcasses for this study. I am especially thankful to Dr. R. T. Berg, Professor of Animal Genetics who offered much useful advise and assistance during this work and who made many helpful suggestions in the preparation of the text.

To my wife, Linda, I am especially grateful for her constant understanding, patience and encouragement during the months taken to complete this study.

I wish to acknowledge, with deep gratitude, the assistance of Canada Safeway Limited who made their staff and facilities available for a very important part of this work.

I also wish to thank Miss C. P. Patterson and Mrs. R. Brenner for the excellent typing of the text.

Financial assistance was provided to me through a Canada Department of Agriculture Research Grant.

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX

INTRODUCTION

The need for a quick and accurate method of carcass evaluation for beef cattle has become apparent in Canada. Carcass evaluation is of use in three main areas of animal production. It is the end point of breeding, nutrition and management studies with beef animals. Large scale genetic improvement schemes involving meat animals require practical methods for carcass evaluation. Also commercial grading of carcasses depends on simple and accurate methods of evaluation (Carroll, 1966).

The traditional system of applying a subjective grade to animals or carcasses has not proven precise enough for more sophisticated meat and breeding studies. These methods do not accurately indicate the yield of edible meat of a carcass. Also beef producers today are asking for a fairer grading system which rewards the producer of the superior meat carcass.

The purpose of this thesis was to attempt to devise an accurate method of predicting retail yield or cutability of beef cattle carcasses. Failing this I hope to at least clarify some of the problems that face the development of such an equation and to evaluate the predictive value of some of the measurements taken from a carcass. It is hoped that this study will provide information of some use in developing a better grading standard for beef carcasses.

LITERATURE REVIEW

I. Carcass Composition

A. Growth Patterns

An understanding of growth patterns of muscle, fat and bone will aid in determining the optimum slaughter weight for various breeds and classes of cattle.

Butterfield and Berg (1966b) reported that all muscles of the ox do not grow at the same relative speed from birth to maturity. They found muscles that grew slower than average, some that grew at about average and some that grew faster than average. They also reported that quite a few muscles changed relative speed, that is, they started out at one relative speed and then changed to another pattern.

Nutrition, weight, sex and breed can influence the growth of tissues. Butterfield and Berg (1966a) showed that nutrition level influenced only the rate at which muscles grew but not their relative proportions at any given weight. Butterfield et al. (1966) also showed that the muscle:bone ratio of calves was more dependent on carcass weight than calf age. A low level of nutrition only retarded normal development but did not alter the proportions of muscle, bone and fat.

Berg and Butterfield (1968) showed that breed had some influence on the growth of tissues. They showed that at any given age, under similar nutrition, Holsteins had greater size, more muscle, more bone but essentially the same amount of fat as Herefords. They also showed that in the early stages there was little difference in tissue growth between Herefords and Friesian steers when compared on the bases of total muscle plus bone weight. When the fattening stage began

however, the two breeds separated in relative tissue growth with the Hereford steers fattening at lighter weights than the Friesians.

Berg and Mukhoty (1970) showed that the sex of an animal also influences tissue growth. Heifers had a superior distribution of lean to bulls, being higher in proportion of large round muscles and lower in the proportion of neck muscles. Steers fell approximately between the two. Berg (1969) showed that bull carcasses had less fat than heifer carcasses and more lean and a little more bone. Again the steers fell between bulls and heifers but they were more like the heifers in fatness.

B. Muscle and Fat Distribution

It has been assumed that the development of specialized beef breeds has resulted in a higher proportion of retail cuts in the high priced areas of the carcass such as the loin and round. The development of the blocky "beef type" animal was founded on this principle. The study of Butterfield (1965) casts doubt that any redistribution of muscle has actually occurred in the evolution of "improved" breeds. He reported that the percent of expensive muscles for Polled Hereford, Hereford, Angus, grade Brahman, half Brahman and unimproved Shorthorn was 55.92, 55.59, 55.39, 56.35, 56.65 and 56.11 respectively, none of which was significantly different from any other. The unimproved Shorthorn had no selective pressure toward beef type since its introduction during the early settlement of Australia, and had been left to survive as best it could in the 'outback' of that country. This unimproved beef breed slightly excelled some of the more

carefully selected breeds in percent of high priced muscle, though not significant statistically. This suggested that selection for beef type had not successfully concentrated muscle into the expensive areas.

However breeders have successfully shifted fat (Ledger, 1959 and Callow, 1962). Callow found that the more an animal fits the traditional beef type conformation, the greater the deposition of subcutaneous fat. Dairy cattle, on the other hand, had less subcutaneous fat but more intermuscular and body cavity fat than the beef breeds (Branaman et al., 1962 and Carroll et al., 1964). The nature of fat deposition is not as yet well understood and more work will have to be done to explain some of the differences which exist between breeds.

II. Predicting Cutability

Prediction of the retail worth of a meat animal has become increasingly important to the meat industry and to animal research. The end point of beef production is the saleable portion at the retail level and considerable effort is at present directed toward accurate and simple estimation of cutability.

A. Cutability

Cutability or retail yield may have many definitions. Unfortunately it does not always mean the same thing to everyone. Researchers have used many different definitions of cutability when reporting their findings. Kropf and Graf (1959) defined it as completely boneless retail cuts trimmed of fat to a tolerance of not more

than 1/2 inch remaining with all surface connective tissue removed from steaks. Brungardt and Bray (1963) defined cutability as the partially boned retail cuts from the wholesale chuck, rib, loin and round trimmed to 3/8 of an inch of remaining fat. They did not include the lean trim from the four above cuts. Fitzhugh et al. (1965) defined cutability as the pounds of retail boneless steak and roast meat. Busch et al. (1969) defined it as kg of closely trimmed (6 - 7.5 mm) of practically boneless retail cuts and lean trim (20 - 30% fat) from one side of a carcass. These and other interpretations of yield can be confusing and it would be a great help if some standard definition could be adopted.

Consumer preferences can also complicate the definition of cutability. Meyer and Ensminger (1952) found that as one moved from region to region, from one income level to another, and from year to year, preference for certain cuts, size of cuts and fat trim varied. If their findings are still true, this means that a carcass cut in one area could have a different cutability than the same carcass in another area, thus further complicating the definition of cutability.

Cutability can vary from one animal to the next even within the same grade and weight range and it nearly always varies between different grades (Goll et al., 1961a). The traditional method of assigning a value to the carcass has been to grade it. It was assumed that the higher the grade the better the carcass was suited for its ultimate destination. Many researchers have begun to question whether the method used to grade carcasses actually selects the best carcasses (Kropf and Graf, 1959; Murphey et al., 1960; Goll et al., 1961b; Cobb and Ovejera, 1965; Fitzhugh et al., 1965 and Johnston et al., 1967).

Cobb and Ovejera (1965) found only a small correlation between cutability and the U.S.D.A. grade ($r = -0.12$). Kropf and Graf (1959) reported that as grade improved, cutability decreased. Cutability depends on the proportions of fat, lean and bone which make up the carcass. The higher the proportion of lean relative to fat and bone, the higher the cutability. These proportions can vary considerably depending on the age of the animal and the nutritional treatment it has received prior to slaughter (Butterfield and Berg, 1966a). Graders have tried to select those animals with the best proportions for the top grade. To accomplish this end they chose carcasses of good conformation, that is, those showing thick rounds and full loins, indicating meatiness and enough fat to cover the carcasses. Goll et al. (1961a) found however that finish or degree of fatness had more influence on yield than did conformation. This agrees with the work of Johnston et al. (1967) and Abraham et al (1968). It is logical to assume that an estimate of cutability should therefore place more emphasis on degree of fatness and less on conformation than does the traditional grading system.

B. Carcass Grade

The need for a system of grading beef cattle carcasses has been recognized for a long time. Different grading systems have been adopted as the needs of the industry or consumers changed. A grading system should classify carcasses into categories which are in accord with consumers desires and it should form the base for fair and equitable pricing of the product to the consumer, retailer and producer. A grading system should also reflect quality and cutability

to the consumer and retailer (Berg, 1970).

The present grading system used in Canada is based on maturity (age), fatness and conformation. Grade is awarded upon visual inspection by a Federal inspector. Essentially it is determined by subjectively appraising the conformation, finish and quality of a carcass. Those carcasses judged to have deep, fleshy loins and rounds, have adequate fat cover and be of proper age are placed in the top grade. The subjective nature of the grade, without benefit of rigid guidelines, leaves much room for human error. The system used in the United States is similar. In addition to this simple grade, the U.S.D.A. adopted an optional and more detailed yield grade. Any reference made to grade in this review refers to the simple grade of both countries.

Bray (1963) wrote, "One of the simplest, perhaps most used, research tools in evaluating live animals and carcasses is grade. It is also one of the most meaningless research tools used in meat animal research."

The major criticism of grade as an estimate of meat yield is that it does not account for the wide variations in yield from carcasses which have the same grade. Finish plays such an important role in determining yield that some more refined estimate of total fat should be used to make a grading system useful (Goll et al., 1961a).

A considerable amount of work has been done on carcasses of different grades. It has been shown that the correlation between grade and cutability is usually small and nearly always negative (Kropf and Graf, 1959 and Cobb and Ovejera, 1965). It has also been shown that grade is often highly correlated with total carcass fat

and that as grade rises total fat increases (Kropf and Graf, 1959 and Woodward et al., 1960). Kauffman (1965) and Carroll (1966) reported that as grade increased percent of bone decreased. This phenomena is explained by Berg and Butterfield (1966) who showed that bone grows at a fairly constant rate relative to age and that fat is deposited at an increasing rate approaching maturity. Since higher grading carcasses are fatter they will have relatively more soft tissue compared to bone than lower grading carcasses.

Few people would disagree with the evaluation of grade made by Bray in view of the quantity of evidence which supports his thinking.

C. Relation of Linear Carcass Measurements and Cutability

1. Fat Thickness

Hammond (1932), working with sheep, found that as fatness increased so did dressing percent. Butchers at the time tended to buy these fatter animals thinking the higher dressing percentage meant more saleable meat. Some people today still tend to emphasize dressing percentage for the same reason. However this reasoning is erroneous. Hammond found that as fatness increased the percent lean decreased. Palsson (1939) suggested that the ideal joint is one with a high proportion of muscle to bone and with enough fat to cover the meat to prevent drying. Also working with sheep, he discovered that depth of fat over the rib-eye was highly correlated to total carcass fat. He reported correlations of 0.94 and 0.70 between total fat and thickness of rib-eye fat for hoggets and lambs respectively. McMeekan (1941) reported similar results with swine.

For a number of years the most common fat measure was the average of three measurements at different locations on the rib-eye at the 12th rib. These locations have become quite standard and are still commonly used (Cobb and Ovejera, 1965; Fitzhugh et al., 1965; Judge et al., 1966 and Epley et al., 1970).

Cole et al. (1962) in attempting to develop a prediction equation for retail yield of lean meat in beef, found that a single measurement of fat at the 12th rib was a more accurate predictor of fat than was the average of the three measurements taken at the same rib section. He found the single measurement had a correlation of 0.86 with total carcass fat. Ramsey et al. (1962), Henderson et al (1966) and Abraham et al. (1967) supported these findings. Murphey et al. (1960) however, found no difference between the accuracy obtained in predicting total fat from the average of three measurements or from a single measurement at the 12th rib-section. Gottsch et al. (1961) supported these findings. All researchers, however, found highly significant correlation between total fat and either measure. Bray (1963) and Brungardt and Bray (1963) compared the correlations obtained between total fat and fat thickness measurements taken at the chuck, 12th rib-section and the loin. Both reported that the 12th rib-section measurements provided the highest correlations, thus the best indicator of total fatness. This is indeed fortunate because this measurement is very easy to obtain from any "ribbed" carcass. Judge et al. (1966) provided similar results using sheep.

Brackelsberg and Willham (1968) developed a method of live probing beef cattle to measure fat thickness. They found that the results obtained from live probing at the 12th rib-section produced

even better correlations with total fat than did subsequent single measurements at the same location on the carcass.

2. Kidney Fat

Kidney fat can easily be collected and weighed during the slaughter operation. It could be a useful predictor of cutability if it had a good correlation with total fat or lean.

Fitzhugh et al. (1965) found kidney fat quite useful in an equation to predict total steak and roast meat. Kidney fat and carcass weight together accounted for 90 percent of the total variation in cutability between carcasses. Average fat thickness of the 12th rib-section and carcass weight accounted for 83 percent of the variation. Cobb and Ovejera (1965) reported a correlation of -0.65 between yield of trimmed cuts and kidney fat weight. This is in agreement with results obtained by Murphey et al., 1960, 1963; Goll et al., 1961b; Brungardt and Bray, 1963; Stringer et al., 1963 and Epley et al., 1970. Fitzhugh et al. (1965) found a highly significant correlation between kidney fat and average carcass fat thickness. Henderson et al. (1966) on the other hand, reported only a low correlation of 0.26 between these measures.

The breed of the animal may strongly influence the amount of kidney fat normally deposited. Branaman et al. (1962) observed that percent kidney fat in Herefords was about the same as in Holsteins. Carroll et al. (1964) reported that Herefords had more trimmed surface fat than Holsteins even when the Holsteins were fed 6 months longer. Cole et al. (1962) reported similar results. If kidney fat weight is nearly the same but surface fat different, the

ratio of surface fat to kidney fat would not be the same for the two breeds. These results indicate that one prediction equation developed with one of the breeds would not be as useful in predicting lean in the other breeds if kidney fat were used in the prediction. It does seem apparent that kidney fat does give a good indication of total fatness within a restricted class of animals, but its usefulness when various classes are involved is not clear.

3. Rib-eye Area

The area of a cross-section of the longissimus dorsi muscle or rib-eye has often been used to evaluate or predict total muscle. It is one of the largest muscles in a carcass and it is felt that an estimate of its size would be a good indicator of total muscle. The longissimus dorsi grows rapidly after birth but soon slows down to about an average rate for all carcass muscles (Butterfield and Berg, 1966b). It should then give a fairly good idea of total muscle development.

Palsson (1939) observed that the length of the longissimus dorsi plus depth gave a correlation of 0.77 with total muscle in sheep. McMeekan (1941) found similar results in swine. Orme et al. (1960) found that the weight of the longissimus dorsi was highly correlated (0.92) with the weight of total carcass lean in cattle.

The use of the rib-eye area at the 12th rib-section in cutability predictions has been questioned (Ramsey et al., 1962; Kennick et al., 1963; Fredeen et al., 1964; Judge et al., 1966; Abraham et al., 1967 and Johnston et al., 1967). Cole et al. (1960) compared their work with beef with Palsson's work in sheep and found

a correlation of only 0.43 between rib-eye area and weight of carcass lean. They observed that carcass weight was more highly correlated with total lean (0.77) than was the measurement of the longissimus dorsi used by Palsson. Goll et al. (1961b) noted similar results using rib-eye area. They showed that correlations between rib-eye area and animal size were large but when adjusted for carcass weight these correlations became small. Fitzhugh et al. (1965) also found that carcass weight accounted for most of the variation in rib-eye area. They found that alone, rib-eye area had a correlation of 0.30 with weight of boneless roast and steak meat, but when adjusted for carcass weight, the correlation dropped to 0.01. A correlation of 0.57 between rib-eye area and weight of retail cuts was reported by Epley et al. (1970). This correlation fell to -0.12 when percent retail cuts was used in place of weight.

In contrast, Cobb and Ovejera (1965) found that the correlation increased when rib-eye area was adjusted for weight. However they did not feel that the increased correlations made it any more useful in a prediction equation for cutability. Other workers have also found significant correlations between rib-eye area and yield (Stringer et al., 1963, with market beef and Latham et al., 1966 with lambs). Neither attempted to remove the effect of carcass weight and both used weight as a measure of yield. Latham felt that carcass weight was of little use in lambs because of their uniform slaughter weight.

One would have to conclude from the above reports that the use of rib-eye area is of low predictive value when attempting to predict cutability. It may be of some use in predicting total lean

in a carcass.

4. Other Linear Carcass Measurements

In an attempt to predict yield, some researchers have tried to correlate linear body measurements with yield of muscle, fat and bone. McMeekan (1941) concluded that external linear carcass measurements were of little use as predictors of muscle and bone. Fredeen et al. (1964) supported this finding by reporting that carcass length was a very poor indicator of yield, accounting for only nine percent of the variation in cutability of swine. All measurements reflecting absolute body size of beef cattle are highly correlated with body weight and weight of retail yield (Goll et al., 1961a and 1961b). They were not able to obtain any good correlations between linear measurements and percent yield unless adjusted for weight. Length of body, length of hind leg, circumference of round, length of loin and depth of body became statistically significant with correlations of 0.39, 0.52, -0.37, 0.44 and 0.55 respectively with cutability, when adjusted for equal body weight. Birkett et al. (1965) found very similar results. They made one valuable observation that linear measurements were more correlated with weight of yield than with percent of yield. As an example, they found that the correlation between pounds of retail cuts and length of loin was 0.59, but it was only 0.09 with percent yield. Carcass weight was highly correlated with pounds of yield (0.97) but, when correlated with percent yield, the coefficient fell to -0.52. This supports the argument that measurements reflecting absolute size are better indicators of total yield than of percent yield. Cobb and Ovejera

(1965), Abraham et al. (1967) and Abraham et al. (1968) found similar results.

Thornton and Hiner (1965), using a different technique, calculated the volume of the round in beef and found a correlation of 0.80 with total lean. This was again a measure of absolute size.

Due to the large influence of fat on the cutability of a beef carcass any carcass measurement which excludes this variable will not provide as satisfactory an estimate of the percent yield of lean cuts as if it were included.

D. Dissection Into Fat, Lean and Bone

1. Total Dissection

The most accurate method of determining percent lean, fat and bone of a carcass is to separate it physically into these components. This can be anatomically (Hammond, 1932; Orme et al., 1960 and Butterfield, 1965), which is very accurate; or, roughly into lean, fat and bone, with no distinction being placed on individual muscles (Cole et al., 1960; Branaman et al., 1962; Field et al., 1962; Latham et al., 1966).

Anatomical dissection requires a great deal of time and skill to remove the individual muscles properly from the carcass. It does, however, provide more information concerning the relative importance of any one or any group of muscles to total lean. Rough dissection may make up in time for what it loses in precision. It is slightly more difficult to remove all the tendon from the muscles and some intermuscular fat would also remain with the lean, but on the whole it could be very acceptable. The final decision as to which method to

use will ultimately depend on the time and money available.

2. Partial Dissection

To further save time in estimating lean, fat and bone, some researchers have attempted to correlate the proportions of lean, fat and bone of a single joint or wholesale cut to the carcass total. If a single joint is a good estimator of the total, then it would be unnecessary to dissect the whole carcass (Callow, 1962; Cole et al., 1962; Kennick et al., 1963; Clark et al., 1964; Tulloh, 1964; Butterfield, 1965; Adam and Smith, 1966; Jobblin and Carter, 1966a and 1966b and Busch et al., 1968).

In 1946 Hankins and Howe developed a formula to predict cutability from the 9-10-11th rib cut. Cole et al. (1962) used this formula and found that the correlation between actual percent lean and estimated percent lean was 0.95 using 81 beef carcasses. Cole found however that this formula tended to overestimate the yield.

Callow (1962) used the muscles of the 12-13th rib-section, neck, shoulder, thorax, foreskin, loin, pelvis, leg and hindskin independantly, to predict total carcass muscle. He found that the muscles of the foreskin gave the best indication of total lean ($r = 0.90$, S.E. = 5.54 kg). The muscles of the loin were the next best ($r = 0.87$, S.E. = 6.39 kg). A re-analysis of Callow's data showed that he could have appreciably reduced the standard error by including carcass weight in the prediction equation (Harrington and King, 1963). Cole et al. (1960) also found that carcass weight improved the estimate of lean in their own work.

Callow also tried to predict fat and bone. He reported that the shank bone (radius-ulna) was the most highly correlated with total bone (r = 0.98, S.E. = 0.78 kg). He found that the thorax fat was the best indicator of total fat (r = 90, S.E. 1.79 kg) followed by the 12-13th rib cut. Clark et al. (1964) also found the shank to be the most accurate estimator of muscle and bone, but Cole et al. (1960) reported that the shank was only third, preceded by the round and the chuck. Cole et al. found a correlation of 0.95 between pounds of separable round lean and carcass lean but a correlation of only 0.81 between pounds of shank lean and carcass lean. By including carcass weight into a multiple equation he improved the correlation to 0.97 and 0.89 respectively with standard errors of 4.38 and 8.50 pounds of lean. Brungardt and Bray (1963) also found the round to be the most highly correlated with retail yield.

Brungardt and Bray (1963) found that the weight of a particular wholesale cut was not highly correlated with yield, but this same cut trimmed to 3/8 inch fat had a much higher correlation. The weight of all the wholesale cuts, trimmed to a standard fat thickness, accounted for 74 percent (r = 0.86) of the variation in cutability. By including the percent trimmed round with a measure of fat over the rib eye they were able to predict cutability with a standard error of only 1.4 percent. Henderson et al. (1966) reported similar results. It is likely that complete dissection of the round would have increased the accuracy of their predictions as Cole et al. (1960) reported.

Workers using other species of meat animals have obtained similar results. The rib cut in sheep gave the best estimate of lean, fat and bone, with the leg and loin nearly as accurate (Hankins, 1947).

Field et al. (1962) and Latham et al. (1966) agreed. The leg (ham) joint was the best indicator of fat and lean but the loin predicted bone more accurately in swine. The loin was also a very useful joint with which to predict fat and lean (McMeekan, 1941). Adam and Smith (1966) reported that the rib-end of swine best indicated total fat, lean and bone. These findings agree with Jobblin (1966b), although all joints had similar predictive value.

Nearly all joints, or wholesale cuts, when dissected or separated into fat, lean and bone, could be used quite successfully to predict carcass yield. It is expected that the larger wholesale cuts would likely be better estimators of carcass yield than smaller cuts because of a part to whole relationship. The larger the cut, the more its cutability would affect the cutability of the remaining carcass. The joint used would depend on the degree of accuracy required and the cost of sacrificing certain primal cuts.

Several criticisms can be directed at the use of wholesale cuts to predict total lean. The biggest criticism is that, since a wholesale cut does not follow any anatomical division, no two people will ever cut a carcass up in exactly the same way (Carroll, 1966; Jobblin, 1966b). One butcher may tend to emphasize one cut more than another and this must introduce bias into results.

Another criticism is that all countries do not follow the same procedure to divide up a carcass. This makes it difficult to apply a prediction equation in more than one country or region.

A final criticism is directed at the use of trimmed wholesale cuts as part of a prediction equation. It would be very difficult to obtain standard results from one worker to the next, or even from day

to day, where judgement must be used to trim the fat to any specified thickness.

Much can be said in favor of using only whole muscles which fall in any anatomical joint. These are not subject to any of the above criticisms. The only variations would be entirely the result of differences in animals, and equations based on these joints should be more accurate and repeatable.

E. Other Methods of Predicting Cutability

1. Ultrasonics

The use of high frequency sound waves (ultrasonics) to estimate the rib-eye area and covering depth of fat has been used by several workers since Temple et al. (1956) first reported on its use in livestock. Stouffer and Wellington (1960) found highly significant correlations between estimated rib-eye area and actual rib-eye area. Estimated fat depth and actual depth was also correlated. No standard errors were reported but the correlations for rib-eye area ranged from 0.22 to 0.85 in three trials with steers. The correlations for fat depth ranged from 0.35 to 0.54. Stouffer and Wellington (1960) repeated these trials using swine and obtained higher correlations. Hedrick et al. (1962) reported similar findings in their work with beef. McReynolds and Arthaud (1970) found a highly significant correlation (0.58) between the estimated fat thickness of beef at the 12-13th rib-section and the actual depth measured on the carcass.

None of the above authors attempted to predict lean or cutability using their ultrasonic methods. Isler and Swiger (1968) however found the correlation between estimated fat thickness (by

ultrasonics) and percent lean cuts to range from -0.45 to -0.63 in several trials with swine. The average correlation between actual carcass fat thickness and percent lean cuts was -0.62. They did not report standard errors but they felt that lean could be predicted adequately by using 6 ultrasonic back fat measures and liveweight to obtain a correlation of at least 0.8.

Stouffer et al. (1961) compared the results obtained by two technicians to determine if the method was repeatable and devoid of operator bias. When the operators tested the same animals over again one obtained a repeatability correlation of 0.75 and the other 0.90. When they tested the animals that the other technician had previously tested their results correlated 0.81 in one trial and 0.87 in another. All correlations were highly significant and Stouffer et al. concluded that the method was reliable. They felt that the biggest error resulted from interpretation of the photographs. The results of one technician were nearly always more highly correlated to actual measurement than the other regardless who actually took the pictures. Stouffer (1963), Davis et al. (1966) and McReynolds and Arthaud (1970) supported these findings.

2. Specific Gravity

Fat, lean and bone have different densities and it is felt that with bone being nearly the same proportion in each carcass, the proportions of fat and lean can be accurately estimated by the specific gravity of that carcass. Brown et al. (1951) first used this method to estimate lean and fat of pork carcasses. Kraybill et al. (1952) performed similar tests on beef cattle, although they attempted to

predict only fat. Barton and Kirton (1956) also estimated total fat in lamb carcasses by the specific gravity method. They reported a correlation of -0.98 between estimated fat and percent fat of the half (S.E. = 1.31%). A much lower correlation of -0.49 between percent carcass fat and estimated fat in lamb carcasses was reported by Field et al. (1962). They also estimated percent lean and reported a correlation of 0.47. In their work, however, no other carcass measurement gave a higher gross correlation when related to carcass composition. Cobb and Ovejera (1965) reported a highly significant correlation of 0.69 between yield of trimmed retail cuts and specific gravity of beef carcasses adjusted to equal weight. By including specific gravity into their multiple regression equation to predict total yield, the multiple regression coefficient increased to 0.78 from 0.69.

In opposition to the above findings Latham et al. (1965) found that specific gravity could not be used as a reliable estimate of lean in lamb carcasses because the standard error was too large. This view based on results with lambs of similar grade and carcass weight was supported by Field et al. (1962).

More work needs to be done with beef carcasses to determine if specific gravity can be used to predict lean and fat or cutability.

3. Potassium 40

Stable potassium has a constant percent of radioactive potassium 40 (K^{40}) which can be measured by isotope counters (Ward et al., 1967). Some workers have tried to estimate the proportions of lean, fat and bone in carcasses by measuring the residual radioactivity of K^{40} which appears in fat, lean and bone in consistantly

different amounts.

Kirton et al. (1960) reported only low correlations between the K^{40} count from lamb carcasses and total lean. The correlations were much higher for live, unwashed lambs. Washed lambs gave correlations midway between those of the carcass and unwashed lambs. Kulwick et al. (1960a, 1960b) reported a very high correlation between the K^{40} count of pork hams and weight of carcass lean ($r = 0.96$, S.E. = 0.38). Kulwick et al. (1961) reported similar high correlations between the K^{40} count of the round of beef steers and percent carcass lean ($r = 0.798$, S.E. = 2.10). The correlation between the K^{40} count of fat and percent fat was equally high ($r = -0.865$, S.E. = 1.65).

None of the authors cited above attempted to work out any prediction equations incorporating K^{40} count with any other variables so it isn't known how useful this method would be to predict cutability.

In recent reports some doubt has been cast on the reliability of the K^{40} count as an indication of fat, lean or bone content of a carcass. Stant et al. (1969) showed that breed of pig had a significant effect on the K^{40} count. They also showed that as weight increased, K^{40}/kg of sample decreased. They showed this to be largely a product of differing degrees of fatness. When the potassium concentration was expressed as gm of potassium/kg of fat free sample, the effect of weight and breed largely disappeared. Bennink et al. (1968) found rather inconclusive results in beef steers. The average weight of potassium /kg of fat free dry sample of fat was 12.6 grams. The average for samples of fat free lean was 14.0 grams. One of their test steers showed a reverse of 18.7 gm in the adipose tissue and 16.8 in the lean sample. They could not explain this and therefore

questioned the reliability of the whole technique. Lohman and Norton (1968) demonstrated that the amount of potassium in the diet of steers had a significant effect on the potassium concentration of tissue samples. By feeding low potassium feed for seven days the K^{40} count was reduced 56 percent. They found the lean tissue to contain the highest potassium concentration and the fat to contain the least. This supported work done by Ward et al. (1967) who found a similar trend.

It is apparent that continued work will have to be done with K^{40} to determine if there is any use for it in predicting beef carcass cutability or lean.

F. Prediction Equations

Many of the authors cited in this review have submitted prediction equations, using various combinations of measurements, which they felt adequately predicted carcass yield. Unfortunately yield does not mean the same thing to each author, thereby making it difficult to compare the various equations.

Those authors reporting yield as cutability or percent lean are listed below.

Hankins and Howe (1946)

Percent yield of lean = 16.08 + 0.80 (% lean in the 9-10-11th rib cut)

(R = 0.95)

Cole et al. (1960) found that under their conditions this formula tended to overestimate lean.

Murphey et al. (1960)

Percent boneless and semi-boneless cuts from the round, loin, rib and chuck = 51.34 - 5.784 (fat thickness over rib eye, in.) - 0.0093 (carcass weight, lb.) - 0.462 (kidney fat, lb./cwt. of carcass) + 0.740 (rib-eye area, sq. in.).

(R = 0.912, S.E. = 1.63)

This equation was developed using 750 slaughter cattle of mixed breeding. Murphey et al. (1963) found that the standard error of this equation could be reduced if a subjective evaluation of total carcass fat was used to adjust the measurement of fat over the rib eye. The standard error of their 1963 data was reduced from 1.53 to 1.39 with this adjustment. Ramsey et al. (1962) found that they could improve the correlation by removing rib-eye area from the above equation.

Brungardt and Bray (1963)

Percent retail yield = 16.64 + 1.67 (% trimmed round) - 4.94 (single fat measure over rib eye, in.)

(R = 0.81, S.E. = 1.55)

This equation was developed using 33 sides of beef from three weight groups averaging 274, 312 and 348 pounds. They noted that kidney fat and rib-eye area added very little additional accuracy to this equation.

Cobb and Ovejera (1965)

Percent trimmed retail cuts = 75.3859 + 0.0317 (chilled carcass wt., lb.) + 0.0361 (rib eye area, in.) - 0.0303 (fat thickness over rib eye, in.) - 0.8893 (kidney fat wt., lb.)

(R = 0.69)

This equation was developed using 103 Hereford cattle. Kidney fat predicted most of the variation in yield. By adding specific gravity of the carcass to the equation, the correlation was increased to 0.78.

Birkett et al. (1965)

Percent closely trimmed wholesale cuts = -8.49 + 0.05 (carcass wt.) + 4.6 (adjusted forearm circumference) + 3.43 (adjusted round circumference) + 5.63 (adjusted loin length) - 1.44 (adjusted rump length)

(R = 0.82, S.E. = 1.55)

This equation was developed using 32 steer carcasses which varied widely in grade. The adjustment was made by dividing the variable by the hundredweight of carcass.

Other authors choose to predict yield as weight of either lean or retail cuts. These equations are listed below.

Callow (1962)

Kilograms of carcass muscle = 9.510 - 35.66 (Foreshin muscle, kg)

(R = 0.90, S.E. = 5.54)

Kilograms of carcass bone = 3.690 + 15.51 (radius-ulna bone, kg)

(R = 0.97, S.E. = 0.780)

Harrington and King (1963) re-analyzed Callow's data and they were able to reduce the standard error of his muscle equation by including carcass weight and the weight of the foreshin joint.

Cole et al. (1962)

Pounds of carcass lean = 11.73 - 1.73 (fat thickness over rib eye, mm) + 0.289 (carcass wt., lb.)

(R = 0.88, S.E. = 5.8)

This particular equation was developed using 132 carcasses representing seven breeds of cattle and their crosses. They also reported equations for beef type and dairy type steers. Each gave a better prediction of its own type than did the combination equation. The standard errors were not greatly different however.

Clark et al. (1964)

Yield of muscle = 9.1008 - 45.0288 (fat thickness over rib eye, cm) + 1.0686 (carcass wt., lb.) + 0.0240 (shin muscle, kg)

(R = 0.99)

Yield of fat = 75.188 + 99.352 (fat thickness over rib eye, cm.) + 0.4499 (carcass wt., lb.)

(R = 0.96)

Yield of bone = - 1246.55 + 16.7413 (shin bone wt., gm) + 4.6399 (carcass wt., lb.)

(R = 0.99)

These equations were developed using 97 carcasses of widely different grades and weights. No standard errors were given so it is difficult to determine the accuracy of these equations.

Fitzhugh et al. (1965)

Pounds of steak and roast meat = 27.81 - 29.94 (average fat thickness over rib eye, in.) + 0.4493 (carcass wt., lb.)

(R = 0.91)

This formula was developed from 152 Hereford carcasses grading low standard to high choice (U.S.D.A.). They reported that by replacing fat thickness with kidney fat, the multiple correlation became 0.95. They also noted that the addition of rib-eye area to the equation did not improve it.

EXPERIMENTAL

I. Objectives

This research project with beef cattle was begun with three main objectives:

i) to study the relationships of certain carcass measurements to cutability and percent carcass muscle and to determine which measurements most accurately reflected these variables;

ii) to determine which combination of variables could most easily and most accurately predict cutability or percent carcass muscle; and

iii) to compare cutability and percent carcass muscle as end points for carcass appraisal.

II. Materials and Methods

A. Experimental Animals

Some of the cattle used in this experiment were obtained from the Alberta Beef Cattle Performance Association (ABCPA) test station at Bassano, Alberta, where progeny tests have been conducted for a number of years. From 1963 to 1967 carcass data were available from a total of 165 steers and 38 heifers. These animals were fattened on a commerical ration and were slaughtered at a Calgary packing plant. One side of each carcass was delivered to a retail store of Canada Safeway Ltd. where cutability was determined. In 1967 the remaining side of a number of these carcasses was dissected into muscle, fat and bone at the University of Alberta Meat Laboratory. Data from nine such steer carcasses were included in this research. Further information was gathered from 38 of the steer carcasses by dissection of one shank into lean and bone.

In addition, data were gathered from 40 steers from the University of Alberta Ranch at Kinsella, Alberta, during 1966 and 1967. All of these animals had one half of the carcass carefully dissected into muscle, fat and bone following the method of Butterfield and May (1965). The remaining half was delivered to local retail stores of Canada Safeway Ltd. where cutability was determined.

The breeds represented in this study are listed in Table 1. One hundred and forty animals were purebred and 78 were crossbred. The breeding of 15 steers and 10 heifers was not known and they were thus listed as Other.

TABLE 1

Breed and breed crosses of 243 steer and heifer carcasses used in cutability experiment

Breed	ABCPA Steers					ABCPA Heifers			Kinsella Steers	
	1963	1964	1965	1966	1967	1965	1966	1967	1966	1967
Hereford	17	13	12	24	28		8	20		
Angus	2	4	2	2	2					
Red Angus										
Shorthorn			2							
Charolais				4						
British x British[a]	8	3	2	6	7				3	
British x Charolais	7		3						15	11
Mixed[b]									11	
Other[c]	2	—	15	—	—	10	—	—	—	—
Total	36	20	36	36	37	10	8	20	29	11

a. Hereford, Angus, Red Angus and Shorthorn represent the British breeds.

b. Multiple crosses of Hereford, Angus, Galloway, Charolais or Brown Swiss.

c. 1963 steers are Santa Gertrudis x Angus. The other groups are of unknown breeding.

The University cattle were castrated in the fall after weaning and were promptly put into the feedlot for fattening. The ration consisted of rolled barley and oats in a ratio of 3 to 1 by weight plus 5 percent of a protein-mineral-vitamin supplement. Cut hay free choice was fed also. A more comprehensive discussion of feeding and management of the Kinsella cattle can be found in Berg and McElroy (1968). All animals were fed to at least 430 kg live-weight before slaughter. These judged underfinished at that weight were fed longer.

The male ABCPA cattle were castrated prior to weaning by the contributors. After arriving at the test station they were fed a standard fattening ration until judged ready to go to market grading low Choice.

B. Slaughter Procedure

When the cattle reached market weight, they were shipped to local packing plants where they were slaughtered in the usual manner. Hot carcass weight was recorded after removal of the hide, head, feet, tail, internal organs and kidney knobs. The kidney fat was weighed with any loose channel fat after the kidney had been removed. After 24 hours in the cooler, the left side of each carcass was ribbed between the 11th and 12th ribs and the rib-eye area and depth of rib fat were measured by a government grader. From some animals in 1966 and 1967 the right shank was removed at this time for anatomical dissection.

The following data were collected from the slaughter procedure:

Carcass grade - All carcasses were graded according to the Government of

Canada grading standards by official graders. These grades are coded in our research as Choice - 1, Good - 2, Standard - 3 and Commercial 3 - 0. Commercial 3(C3) carcasses are judged to be overfat. Since the degree of fatness increases as one goes from Standard to Choice, to be consistent with this trend, it was decided to place C3 carcasses before Choice. This is justified because the degree of fatness is one of the important standards used to evaluate carcasses under the present system. Thus C3 carcasses were assigned a zero code.

Hot carcass weight - This was recorded after skinning, eviscerating and washing with the cloth shrouds in place. It represents the weight of both sides of the carcass with the kidney fat and loose channel fat removed with allowances made for the weight of the wet shrouds and hardwear.

Rib-eye area - This is the area of the longissimus dorsi at the 11th and 12th rib section. This measurement was made by a government grader using a plastic grid divided into 1/4" squares.

Average rib fat thickness - Measurements of the subcutaneous fat over the rib at the 11th and 12th rib section were taken at the 1/4, 1/2 and 3/4 points of the outer edge of the longissimus dorsi and averaged. Government graders performed the measurements.

Carcass length - The length of the carcass was measured from the aitch bone to the point where the rib joins the first thoracic vertebra. Carcass length was not taken on the Kinsella steers.

Kidney fat - After the carcasses had been cut in two on the killing floor, the kidney knob and any loose channel fat was removed from both halves. The kidneys were removed and the remaining fat was weighed.

C. Dissection Technique

The dissection technique as outlined by Butterfield and May (1965) was used. It involved the separation of one half of the carcass into individual muscles, fat and bone. Fat was divided and weighed as subcutaneous, intermuscular and body cavity fat at the time of dissection but these weights were later combined for the purpose of this research. All muscles were trimmed of external fat and tendons. The principle followed was that fat and other tissues contained no muscle but muscle contained some other tissues. Tendons were severed from the muscles at the last vestige of muscle. Similarly fat was removed from the surface of the muscles without removing any of the muscle tissue. Tendons were weighed separately at the time of dissection but their weight was later added to total fat. This was done because it was very difficult, in some cases, to separate the fat and tendons and on a retail basis they were treated as fat. All weights of dissected parts were weighed to the nearest whole gram. To minimize moisture loss, wet towels covered the carcasses and the dissected muscles waiting to be trimmed of surface fat and tendon. As soon as a muscle was trimmed it was weighed. Bones were scraped of all fat and loose tendons and weighed immediately. The fat was collected in three containers and weighed separately after the trimming was done.

The shanks which were removed from the right side of some of the steer carcasses were freezer-wrapped and quick frozen until time was available to dissect them. Nine shanks of ABCPA steers were dissected fresh after aging about three weeks, as part of the

total carcass dissection. Forty shanks of Kinsella steers, aged one week less, were also dissected as part of this process. The technique used was essentially the same as used by Butterfield and May (1965) to dissect the shank portion of the total carcass. Only those muscles which were immediately associated with the radius and ulna bones were considered and these included the flexor and extensor groups. The radius and ulna bones were trimmed of all fat and tendon and were weighed and this represented the bone portion of the shank.

The following data were obtained from the total dissection and shank dissection:

Shank muscle weight - The weight in grams of the muscles associated with the radius and ulna bones of the foreleg belonging to the extensor and flexor groups.

Shank bone weight - Weight of the radius and ulna bones of the foreleg. All surface fat and tendon was removed before weighing. Weights were accurate to the nearest gram.

Shank muscle:bone ratio - Shank muscle weight divided by shank bone weight.

Percent carcass muscle - Total dissected muscle from the left side of the carcass as a percentage of the side weight at the time of dissection.

Percent carcass bone - The total bone weight from the left side of the carcass as a percentage of the side weight at the time of dissection.

Percent carcass fat - Combined weight of the subcutaneous, intermuscular and body cavity fat excluding the kidney fat. Tendons

trimmed from the muscle and bone are also added to this total which is expressed as a percentage of the left side of the carcass.

Carcass muscle weight - The weight of the dissected muscle tissue expressed in kilograms.

Carcass fat weight - The weight of the dissected carcass fat expressed in kilograms.

Carcass bone weight - The weight of the dissected carcass bone expressed in kilograms.

Carcass muscle:bone ratio - Carcass muscle weight divided by carcass bone weight.

D. Cutability

After a minimum of one week of aging, the right sides of the test carcasses were delivered to a retail meat store for cutting into retail cuts. The carcasses were first broken into wholesale cuts which were then weighed untrimmed. Then each wholesale cut was in turn reduced to retail cuts and trimmed of excess fat and bone. The bone was removed only as dictated by the store policy and the procedure could be considered as partially boning. The weight of each trimmed retail cut was then taken.

The following data were collected during the retail processing:

Percent retail round - The weight of retail cuts taken from the wholesale round as a percentage of the weight of the untrimmed wholesale round.

Cutability - The weight of the total saleable, partially boned retail cuts expressed as a percentage of the side weight at the

time of cutting.

E. Statistical Procedure

All linear measurements taken at the packing plant were in inches. All weights taken at the plant and retail stores were in pounds and ounces. For the purpose of this study these measurements were converted to the metric system using the conversions of 1 inch equals 2.54 centimeters and 1 pound equals 454 grams. All dissection measurements were taken in the metric system.

An I.B.M. 360 Model 67 computer was used to calculate correlations, analysis of variance, means, variance, standard deviations and multiple linear regressions. Interpretation of the statistics was based on the writings of Steele and Torrie (1960) and Snedecor (1948). The computer programs for all but the analysis of variance were provided by the Department of Computing Science, University of Alberta. The analysis of variance program was provided by the Faculty of Education, University of Alberta. It was a one-way analysis designed to handle unequal classes of observations.

III. Results and Discussion

A. Results

Listed in Table 2 are all the variables used in this research. The number and abbreviation used for each variable is the same throughout this paper and will be referred to in the interpretation of the results.

Table 3 lists the means, ranges and standard deviations for the carcass variables obtained from the slaughter procedure, shank and total dissection and retail cutting for the three groups of animals. The numbers of animals for which different sets of data were obtained are shown.

Simple correlations were obtained among all the variables available for each group of animals. The ABCPA steers had differing amounts of data available from some of the carcasses and these differences are shown. These data are listed in Appendix Tables 1, 2, 3 and 4.

Multiple regressions using selected variables were also obtained from the three groups of animals. The dependent variables are shown and are usually cutability or percent carcass muscle. Some regressions were also obtained with percent carcass fat and percent carcass bone as the dependent variables. The multiple correlation coefficient and standard error of each equation is shown along with the regression coefficient for each of the variables included in the regression. The data for the ABCPA steers were separated according to the number of observations made for each group of variables. These data are shown in Appendix Tables 5, 6, 7, 8, 9 and 10.

TABLE 2

Number and abbreviation assigned to each variable studied

Number	Abbreviation	Variable
1	G	Carcass grade
2	CW	Hot carcass weight in kilograms
3	REA	Rib-eye area in square centimeters
4	AF	Average rib fat thickness in millimeters
5	L	Carcass length in centimeters
6	KF	Kidney fat weight in kilograms
7	%RR	Percent retail round
8	SM	Shank muscle weight in grams
9	SB	Shank bone weight in grams
10	SM/SB	Shank muscle to bone ratio
11	%M	Percent carcass muscle
12	%B	Percent carcass bone
13	%F	Percent carcass fat
14	M	Carcass muscle weight in kilograms
15	F	Carcass fat weight in kilograms
16	B	Carcass bone weight in kilograms
17	M/B	Carcass muscle to bone ratio
18	Y	Cutability

TABLE 3

Means, ranges and standard deviations for various carcass measurements in three groups of animals

Variable+	ABCPA Steers			ABCPA Heifers			Kinsella Steers		
	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
		N=165			N=38			N=40	
G	1.3	1-3	0.52	1.2	1-2	0.37	1.3	0-3	0.64
CW	244	191-316	24.7	192	157-237	24.3	264	240-299	14.6
REA	64	48-86	7.2	51	39-71	7.0	67	53-77	5.6
AF	19	10-33	4.2	20	15-27	3.4	20	8-35	5.4
L	116	107-130	4.2	108	100-119	4.8	--	-	-
KF	5.4	2.7-11.3	1.71	4.6	2.9-8.0	1.15	7.6	4.1-12.3	1.85
%RR	72.93	64.68-78.60	2.44	72.74	67.85-77.74	2.67	74.12	66.86-77.55	2.58
Y	73.15	64.11-79.56	2.87	72.25	66.91-78.04	2.93	74.82	65.68-81.34	3.92
		N=38							
SM	1481	1109-2137	185.9				1691	1278-2096	186.4
SB	943	704-1609	157.0				981	805-1206	102.8
SM/SB	1.58	1.33-1.83	0.125				1.73	1.51-2.04	0.133
		N=9							
%M	59.99	55.83-62.56	1.84				58.22	48.95-67.39	4.14
%B	12.37	11.38-13.70	0.62				12.07	10.38-15.20	1.08
%F	27.74	25.04-33.70	2.40				29.28	18.63-39.98	4.41
M	59.34	49.36-65.21	4.349				74.13	58.88-87.90	6.705
F	30.24	26.82-33.38	2.515				36.84	23.25-54.37	6.426
B	12.66	10.42-14.44	1.097				15.36	12.62-20.96	1.798
M/B	4.86	4.32-5.05	0.222				4.84	3.97-5.26	0.298

+ See Table 2 for description of variable

B. Relationship of Carcass Measurements With Cutability

1. Carcass Grade

The average grade was 1.3 for both sets of steers and 1.2 for the heifers (Table 3). The Kinsella steers were the most variable with a standard deviation of 0.64. This was due, in part, to three carcasses which graded C3 and to a number of heavy hybrid carcasses which did not carry enough finish to grade better than Standard.

The steer carcasses showed a moderately high correlation between grade and cutability as is shown in Table 4. The heifer carcasses showed no significant relationship. The correlation between grade and percent muscle for the Kinsella steers was also highly significant.

TABLE 4

Simple correlations between carcass grade and cutability and percent muscle for three groups of cattle

Variable	ABCPA Steers N=165	ABCPA Heifers N=38	Kinsella Steers N=40
Cutability	0.40 **	-0.03	0.57 **
Percent Muscle	--	--	0.57 **

** Significant at the 0.01 level

The correlations between grade and cutability are actually negative, in spite of the positive numbers shown in the table. In other words, as grade improves cutability decreases. Our choice of numbers to represent the grades for statistical analysis were made to conform to the traditional method of assigning Choice = 1, Good = 2 and Standard = 3. The important concept is that the relationship

between grade and cutability is actually inverse. Kropf and Graf (1959) found a similar inverse relationship with beef cattle as did Cobb and Ovejera (1965). Johnston et al. (1967) reported the same type of results using sheep.

Observing the correlations between grade and some of the Kinsella carcass data (Appendix Table 4) we can see that as grade improves, percent muscle decreases and percent fat increases. The correlations between grade and percent muscle and percent fat were respectively, 0.57 and -0.65 and both are significant at the 0.01 level. Similarly as grade improved, fat thickness over the rib increased (r = -0.52). This is to be expected because the thickness of rib fat plays a major role in the determination of grade under the present system.

From the results of our research on the steer carcasses, one could conclude that grade might be a useful indicator of total yield, in spite of the fact that a negative relationship exists between the two. It appears to be useful only where a wide range of grades exist however. Grade is useless in a class of carcasses where all appear to be similar as was the case in the heifer class. I would hesitate to recommend its continued use in carcass evaluation because it is a subjective and arbitrary evaluation which could vary between graders. In addition to this it does not explain the difference in cutability which exists among carcasses of the same grade. Many researchers agree with this stand (Woodward et al., 1960; Goll et al., 1961; Bray, 1963 and Cobb and Ovejera, 1965).

2. Hot Carcass Weight

The average carcass weight varied considerably among the three groups of cattle (Table 3). The heifers were the lightest with a carcass weight of 192 kg and the Kinsella steers were the heaviest averaging 264 kilograms. The variation within each group was also quite high with the ABCPA steers being the most variable with a standard deviation of 24.7 kilograms. The heifers were next with 24.3 kg and the Kinsella steers were much less variable with a standard deviation of only 14.6 kilograms.

The correlations between carcass weight and cutability were low as is shown in Table 5. Similar low correlations were found with percent carcass muscle. When correlated with the weight of dissected carcass muscle, however, the correlations became very high in both the Kinsella and the nine ABCPA steers. These results agree with many previous workers who have reported high correlations between total weight of lean or saleable cuts and carcass weight (Cole et al., 1960; Orme et al., 1960; Harrington and King, 1963 and Fitzhugh et al., 1965.)

TABLE 5

Simple correlations between carcass weight and cutability, percent muscle and muscle weight for three groups of cattle

Variable	ABCPA Steers N=165	ABCPA Heifers N=38	Kinsella Steers N=40
Cutability	0.10	0.00	-0.06
	N=9		
Percent muscle	0.43	--	0.01
Muscle weight	0.92 **	--	0.61 **

** Significant at the 0.01 level.

A report by Birkett et al. (1965) showed a correlation between carcass weight and weight of closely trimmed cuts of 0.97. However the correlation between carcass weight and percent closely trimmed cuts was -0.52. Brungardt and Bray (1963), Cobb and Ovejera (1965), Abraham et al. (1968) and Epley et al. (1970) found similar negative correlations between percent yield and carcass weight.

The above reports agree fairly closely with what was found in this research although the large negative correlations with percent yield (cutability) were not obtained. This difference might be explained by the fact that the cattle used were of mixed breeding. As was discussed earlier different breeds of cattle fatten at different weights, thus the relationship between carcass weight and total fat would not be as great as it would in a group of cattle that fattened uniformly relative to weight. With a group of animals all of the same breed it would be expected that a heavier animal would likely be fatter than a lighter animal. It shall be shown that the fatter an animal the lower the cutability. This will explain why Cobb and Ovejera and the others obtained high negative correlations between percent yield and carcass weight. In all cases they were using either one breed or one class of breeds (British breeds).

It seems that carcass weight would be of questionable merit in a prediction equation for cutability because it would tend to downgrade a large animal with minimum fat as often can result in crosses with some of the dairy breeds. Carcass weight could be very successfully used to predict total lean if that statistic were required. This was very well pointed out by Harrington and King (1963) when they re-analyzed data reported by Callow (1962). He reported a standard

error of 5.54 kg when predicting weight of lean in a carcass by using the weight of muscle in the shank. By adding carcass weight, Harrington and King reduced this standard error to 3.7 kilograms.

3. Rib-eye Area

From our sample of carcasses the rib-eye area ranged from 48 square centimeters (cm^2) to 86 square centimeters. The Kinsella steers had the largest average area of 67 cm^2 and the ABCPA heifers had the smallest average area of 51 cm^2 as would be expected. The Kinsella hybrids were also the most uniform with a standard deviation of 5.6 square centimeters. The ABCPA steers were the most variable with 7.2 square centimeters.

To see whether there was any difference in rib-eye area in the cattle by year of slaughter an analysis of variance was carried out. The analysis showed a highly significant F value of 9.81. The means were then subjected to Duncan's New Multiple Range Test (Steel and Torrie, 1960) and it was found that the 1967 steers had significantly smaller rib-eye areas. A similar analysis of variance and Duncan's test on carcass weight showed that the 1967 cattle were also significantly smaller ($P < 0.01$). This would suggest a direct relationship between body size and rib-eye area. The correlations between carcass weight and rib-eye area were 0.60, 0.68 and 0.36 for the ABCPA steers, heifers and Kinsella steers respectively. Goll et al. (1961b) found similar high correlations between these two variables. To remove the effect of carcass weight they adjusted rib-eye area for equal carcass weight and found that the high correlations largely disappeared between rib-eye area and body size measurements.

This strong relationship between rib-eye area and body size is further evidenced by the fact that the correlations with rib-eye area are greater with weight of dissected muscle than they are with percent carcass muscle. This difference is not so obvious with the Kinsella steers but shows readily with the nine ABCPA steers (Table 6).

TABLE 6

Simple correlations between rib-eye area and cutability, percent muscle, muscle weight and carcass weight for three groups of cattle

Variable	ABCPA Steers N=165	ABCPA Heifers N=38	Kinsella Steers N=40
Carcass weight	0.60 **	0.68 **	0.36 *
Cutability	0.18 N=9	0.19	0.33 *
Percent muscle	0.49	--	0.51 **
Muscle weight	0.67 *	--	0.58 **

* Significant at the 0.05 level.
** Significant at the 0.01 level.

Orme et al. (1960) found similar high correlations between rib-eye area and weight of carcass lean. Birkett et al. (1965) found a correlation of 0.49 between rib-eye area and weight of closely trimmed cuts. The correlation dropped to 0.00 when percent trimmed retail cuts were used instead of weight. Abraham et al. (1968) and Epley et al. (1970) found very similar trends.

I feel that if rib-eye area is to be used in any prediction of cutability it should be used with caution. It is not well correlated to cutability in any of the groups in this study, and only the Kinsella steers have a significant correlation between rib-eye area and

cutability (Table 6). Rib-eye area suffers much the same handicap as does carcass weight, that being, that it will predict size much better than it will predict percent of yield. In some cases rib-eye increased the standard error of cutability prediction equations rather than improve it.

4. Average Rib Fat Thickness

Thickness of fat over the rib-eye has been shown to be a reliable indicator of total fat by Murphey et al., 1960; Cole et al., 1962; Bray, 1963 and others. It has similarly been shown by these workers that total fat is a good indicator of remaining lean. Therefore thickness of fat has been used by these workers to predict total lean with good results.

In the 205 steer carcasses used in this research, the average fat thickness over the rib ranged from 8 mm to 35 millimeters. The group averages were 19 mm for the ABCPA steers, 20 mm for the Kinsella steers and the 38 heifers averaged also 20 mm (Table 3).

Table 7 lists the simple correlations between average rib fat and several carcass measurements. Some interesting observations can be made by comparing rib fat with various dissection measurements of the Kinsella steers. The average fat thickness was statistically related to percent dissected muscle and percent dissected fat, yet the correlation between average rib fat and carcass muscle weight was not nearly so high. However average rib fat was highly correlated with weight of carcass fat. It therefore appears that rib fat would be more useful to predict percent carcass muscle than total muscle. Rib fat cannot predict total carcass muscle as well as other variables

because of the inconsistent degree of fatness at any one weight in this group of hybrids. The same trend exists for the nine ABCPA steers though not at significant levels.

TABLE 7

Simple correlations between average rib fat thickness and several carcass measurements for three groups of cattle

Variable	ABCPA Steers N=165	ABCPA Heifers N=38	Kinsella Steers N=40
Cutability	-0.32 N=9	-0.40 *	-0.81 **
Percent muscle	-0.52	--	-0.88 **
Carcass muscle	-0.26	--	-0.57 **
Percent fat	0.63	--	0.84 **
Carcass fat	0.54	--	0.86 **

* Significant at the 0.05 level.
**Significant at the 0.01 level.

Average rib fat thickness was more highly correlated with percent carcass muscle than it was with cutability (Table 7). This could be due to variation among butchers and how closely they trimmed the retail cuts. No two butchers would be able to trim to the same degree of fatness. This would cause a greater degree of error variation to exist for cutability than for the more precise total dissection technique.

5. <u>Carcass Length</u>

High and positive correlations were found between carcass length and carcass weight in both steers and heifers. Other high

correlations were found between carcass length and rib-eye area, shank muscle and shank bone weight (Appendix Tables 1, 2 and 3). All of these factors are strongly influenced by body size as suggested by the high correlations between them and carcass weight.

The correlations between carcass length and cutability were low or non-existent. Carcass length seems to be useful only as a measure of body size and has no use in predicting percent retail cuts or cutability. Goll et al. (1961b) and Cobb and Ovejera (1965) reported similar relationships and concluded that length had no place in prediction of cutability.

6. Kidney Fat

Total kidney fat was found to be extremely variable from one animal to the next. The Kinsella steers were the most variable with a standard deviation of 1.85 kilograms. The ABCPA heifers were the least variable with a standard deviation of 1.15 kilograms. The total weight ranged from 2.7 kg to 12.3 kilograms. Kidney fat weight appears to be affected by carcass weight as well as breed. The correlations between kidney fat and carcass weight ranged from 0.47 (ABCPA steers) to 0.32 (ABCPA heifers). These are not high but they are statistically significant. When tested by the analysis of variance for effect of year it was found that the 1963 ABCPA steers were significantly heavier than any other year and also had significantly more kidney fat. The 1966 steers were not significantly different from the 1963 steers but the 29 Kinsella steers were included with this group which may have biased this year as the Kinsella cattle were on the average heavier. These results may not

be conclusive but it appears that breed or type of steer affects kidney fat weight as does the carcass weight.

Many workers have reported that kidney fat weight could be useful in predicting either total fat or retail yield (Murphey et al., 1960, 1963; Goll et al., 1961b; Brungardt and Bray, 1963; Stringer et al., 1963; Cobb and Ovejera, 1965; Fitzhugh et al., 1965; Abraham et al., 1968 and Epley et al., 1970).

We found only very low correlations between kidney fat weight and cutability. Only the heifers showed a significant correlation ($P < 0.05$, Table 8). Henderson et al. (1966) found similar low correlations. The correlations with dissected muscle or dissected fat weight were larger but still not statistically significant. The very low correlation of 0.09 between kidney fat weight and dissected carcass fat weight in the Kinsella steers was surprising in view of the favorable results by the aforementioned workers. This low correlation indicates almost no relationship between these two variables in this

TABLE 8

Simple correlations between kidney fat weight and several carcass measurements for three groups of cattle

Variable	ABCPA Steers N=165	ABCPA Heifers N=38	Kinsella Steers N=40
Cutability	-0.12	-0.32 *	-0.07
Carcass weight	0.47 ** N=9	0.32 *	0.35*
Percent muscle	-0.16	--	0.06
Percent fat	0.34	--	-0.00
Carcass fat	0.56	--	0.09

* Significant at the 0.05 level.
** Significant at the 0.01 level.

class of animals. The mixed breeding of the Kinsella cattle probably explains this low correlation. Work done by Cole et al. (1962) and later supported by Carroll et al. (1964) indicates that dairy breeds have a higher percent kidney fat than do Herefords. A prediction equation designed for Herefords would not be as accurate when used for Holsteins if kidney fat were one of the variables, or so it seems.

The nine ABCPA steers show results more in line with what some of the other workers have found. None of the correlations are significant however because of the small number involved but they do indicate a trend showing usefulness of kidney fat for prediction purposes. All of these cattle were Herefords.

For the moment I am not sure just how useful kidney fat weight can be. It appears that more work will have to be done to evaluate the effect of breed on this variable as well as stage of fattening.

7. Percent Retail Round

Percent retail round proved to be a very accurate predictor of cutability. Table 3 shows that the average percent retail round and the average cutability are nearly the same for each group of cattle. The ranges for these two variables are also very similar, as are the standard deviations. The Kinsella steers depart the most from this pattern. Table 9 lists the simple correlations of percent carcass muscle and cutability with percent retail round. High correlations were found in each test group between cutability and percent retail round.

TABLE 9

Simple correlations between percent retail round and cutability and percent muscle for three groups of cattle

Variable	ABCPA Steers N=165	ABCPA Heifers N=38	Kinsella Steers N=40
Cutability	0.81 ** N=9	0.78	0.88 **
Percent Muscle	0.53	--	0.86 **

** Significant at the 0.01 level.

These high correlations are not unexpected however. The round makes up a large portion of the carcass and any relationship found between it and the total carcass would in fact be an expression influenced by the round. This part-whole relationship can play a very important role in correlations, especially if the part is very large. Another factor influenced by the part-whole relationship may be that of butcher performance. A butcher cutting on the round may tend to cut the rest of the carcass similarly. These two things may help to explain why the retail round was such an accurate predictor of cutability.

8. Shank Dissection

The weight of shank muscle was significantly correlated with cutability (Table 10). It was hoped that good correlations would be found as this joint is easily accessible, inexpensive and easy to dissect and would therefore be quite useful in predicting cutability.

A highly significant correlation between shank muscle weight and cutability was found in the Kinsella cattle. The correlation for

TABLE 10

Simple correlations between shank muscle weight and several carcass measurements for two groups of animals

Variable	ABCPA Steers N=38	Kinsella Steers N=40
Cutability	0.34 * N=9	0.62 *
Percent muscle	0.80 **	0.68 **
Carcass muscle weight	0.90 **	0.86 **

* Significant at the 0.05 level.
** Significant at the 0.01 level.

the ABCPA steers was significant at the 0.05 level but much lower. One possible reason for the difference between the two groups of cattle is that all of the shanks of the ABCPA cattle were frozen except for the nine carcasses which were totally dissected. A second possible reason is that the ABCPA steers were stored in the cooler an average of one week longer than the Kinsella steers. These two treatments would cause different amounts of dehydration in the carcasses or shanks and could have affected the results. Whether or not any adverse effect was incurred is not known but it makes the ABCPA shank data suspect because all the shanks were not handled in the same way. It would have been much better to have treated all shanks in the same manner.

The high correlations found between shank muscle weight and carcass muscle weight indicate that total muscling is reflected in the muscling of the shank. The correlations with percent muscle dropped slightly, as indicated in Table 10, but both were still highly

significant. Work by Callow (1962) and Clark et al. (1964) showed similar results. They found the shank joint to be the best predictor of carcass muscle, ahead of both the loin and the round. Cole et al. (1962) found equally high correlations using the shank but they found other joints to be more accurate by a small margin.

9. Carcass Dissection

Anatomical dissection of a carcass into muscle, fat and bone provides a very accurate estimate of cutability. A great deal of time is required to dissect a carcass and for this reason its use would be limited to research purposes or to provide a standard with which to base cutability predictions.

Highly significant correlations were found in the Kinsella cattle, between cutability and percent dissected muscle and percent dissected fat. The ABCPA steers did not show significant relationships between these factors but this may be due more to the small sample size than to the low true relationship.

Carcass M/B showed no significant correlations with cutability. It was significantly related to various bone measurements in the Kinsella cattle but these are of little practical value in estimating cutability.

C. Prediction of Yield by Multiple Linear Regression

Retail yield of beef carcasses has been defined in several ways. Cutability (percent retail yield) and percent muscle are two methods used. Table 11 shows a comparison between the regression

equations predicting cutability and percent muscle using similar sets of variables. (Other combinations of variables were used and these are located in Appendix Tables 5, 6, 7, 8, 9 and 10). In nearly all cases any one set of variables predicted percent muscle more accurately than cutability. This observation is even more significant in the Kinsella steers because the standard deviation of percent muscle was higher (4.14%) than that of cutability (3.92%).

The standard deviation of percent muscle (1.84%) was lower for the nine ABCPA steers than that of cutability (2.72%) but the results were not unlike those for the Kinsella steers. The more accurate prediction equations for percent muscle always produced a standard error considerably lower than the standard deviation for percent muscle. By contrast these same variables did little to lower the standard error for cutability much below the standard deviation.

One major exception to the above trend was found in equations using percent retail round. The part to whole relationship of the retail round to the carcass would likely be the main reason. In the nine ABCPA steers the standard errors of regressions using retail round were much lower for cutability than for percent muscle, in spite of the higher original standard deviation for cutability. The Kinsella data showed the same trend but was not nearly as obvious as in the ABCPA data. In the Kinsella data the standard errors from equations including retail round were reduced to be nearly equal to the standard errors for percent muscle, something no other groups of variables could do.

In Table 12 are listed some of the equations which most accurately predicted cutability or percent muscle. Equation 1 was the

TABLE 11

Multiple regression and standard error of selected variables with percent carcass muscle (11) and cutability (18) in 9 ABCPA steers and 40 Kinsella steers

		ABCPA Steers			Kinsella Steers		
Standard deviation of percent carcass muscle			1.84			4.14	
Variables+	D.V.[a]	R[b]	SE[c]	$(1-R^2)100$[d]	R	SE	$(1-R^2)100$
4	11	0.52	1.67	72.75	0.88	2.02	23.09
4,2	11	0.65	1.61	57.61	0.89	1.94	20.79
4,2,3	11	0.70	1.65	50.30	0.90	1.89	19.18
4,6	11	0.54	1.78	70.73	0.88	2.04	23.09
4,6,2	11	0.65	1.76	57.49	0.89	1.95	20.43
7	11	0.53	1.66	71.80	0.86	2.10	25.18
7,4,6,2	11	0.80	1.55	35.52	0.93	1.58	13.14
8	11	0.81	1.16	35.04	0.68	3.07	53.76
4,8	11	0.88	1.00	22.21	0.93	1.55	13.32
4,8,3	11	0.89	1.04	20.26	0.94	1.53	12.58
4,8,2	11	0.90	0.99	18.10	0.93	1.53	12.76
4,8,3,2	11	0.91	1.06	16.64	0.94	1.47	11.45
Standard deviation of cutability			2.72			3.92	
4	18	0.38	2.69	85.41	0.81	2.32	34.23
4,2	18	0.42	2.85	82.69	0.81	2.34	33.74
4,2,3	18	0.46	3.06	79.30	0.82	2.37	33.58
4,6	18	0.58	2.55	66.13	0.82	2.30	32.60
4,6,2	18	0.65	2.61	58.01	0.83	2.27	30.78
7	18	0.93	1.04	12.76	0.88	1.90	22.91
7,4,6,2	18	0.98	0.85	4.94	0.92	1.62	15.36
8	18	0.47	2.56	77.82	0.62	3.13	62.18
4,8	18	0.55	2.62	69.53	0.86	2.08	26.73
4,8,3	18	0.56	2.85	68.75	0.86	2.08	26.04
4,8,2	18	0.58	2.79	65.89	0.87	2.02	24.48
4,8,3,2	18	0.59	3.11	65.43	0.87	2.04	24.31

a Dependent variable
b R Multiple correlation coefficient
c SE Standard error of estimate
d $(1-R^2)100$ = Percent of variation unexplained by the variables included
\+ For a description of the variables, see Table 2

TABLE 12

Selected multiple linear regression equations most accurately predicting cutability (Y) or percent carcass muscle (%M) for three groups of cattle

Equation No.	Data Set	Dependent Variable	Variables[+] CW	REA	AF	KF	SM	a	R	SE
1	Kin	Y	0.038		-0.620	-0.386		79.96	0.83	2.27
2	Kin	Y			-0.601	-0.278		88.81	0.82	2.30
3	Kin	Y			-0.594			86.58	0.81	2.32
4	Kin	%M	0.025	0.115	-0.642			56.79	0.90	1.89
5	Kin	%M	0.044		-0.697			60.42	0.89	1.94
6	Kin	%M	0.050		-0.703	-0.137		59.90	0.89	1.95
7	Kin	%M			-0.678			71.62	0.88	2.02
8	ABCPA-M	Y	0.042		-0.283	-0.333		70.23	0.44	2.57
9	ABCPA-M	Y	0.031		-0.288			71.08	0.40	2.61
10	ABCPA-M	Y	0.026	0.026	-0.278			70.52	0.41	2.62
11	ABCPA-F	Y	0.090		-0.724	-0.932		73.59	0.68	2.25
12	ABCPA-F	Y	0.054	0.089	-0.687			70.78	0.60	2.44
13	ABCPA-F	Y	0.075		-0.720			71.99	0.58	2.45
14	Kin	Y	-0.055		-0.415		0.010	81.17	0.87	2.02
15	Kin	Y	-0.051	-0.028	-0.428		0.010	82.06	0.87	2.04
16	Kin	Y			-0.491		0.007	73.53	0.86	2.08
17	Kin	%M	-0.046	0.102	-0.466		0.009	56.93	0.94	1.47
18	Kin	%M		0.068	-0.537		0.007	52.30	0.94	1.53
19	Kin	%M	-0.031		-0.511		0.010	60.15	0.93	1.53
20	ABCPA-M	Y	-0.047		-0.397		0.009	76.75	0.66	2.25
21	ABCPA-M	Y	-0.054	0.074	-0.361		0.008	75.52	0.66	2.26
22	ABCPA-M	Y			-0.482		0.004	75.36	0.63	2.28

a - Y intercept
R - Multiple correlation
SE - Standard error of the estimate
+ - For a description of variables see Table 2.

most reliable predictor of cutability in the Kinsella cattle using non-dissection data, but I hesitate to recommend it because of the part carcass weight plays in it. I do not feel that carcass weight should be a factor of grade if a carcass measures up satisfactorily in all other areas. There is some evidence that weight and cutability relationships are influenced by breed and sex and therefore equations which suit one group might be inappropriate for other groups (Berg and Butterfield, 1968). Equation 2 or 3 might be suitable and the standard error of either equation was not much greater than for Equation 1, therefore their use would be preferable.

The ABCPA steer carcasses produced nearly the same results as those from Kinsella. Average rib fat, kidney fat and carcass weight combined to produce the most accurate prediction of cutability (Equation 8).

The ABCPA heifer carcasses followed nearly the same pattern as that of the steers.

It is readily apparent from the above equations that it was more accurate to predict percent muscle than cutability. Equations 1 and 6 used the same variables but the standard error of Equation 6, which predicts percent muscle, was much lower. The same comparison can be made with other similar sets of variables.

Average rib fat thickness appeared in every equation in Table 12. This variable consistently accounted for the largest amount of variation in percent muscle. No equations are shown in Table 12 in which percent retail yield was used, but this was the only variable which explained more of the variation in cutability than did average rib fat. Fat thickness was such a good indicator of

carcass fatness that it should be used in every equation to predict carcass yield.

Wherever the data included shank muscle weight, a reduced standard error resulted. Equation 14 showed the effect of removing kidney fat weight (Equation 1) and including shank muscle weight. The standard error fell from 2.27% to 2.02 percent. When percent muscle was predicted in the Kinsella steers (Equation 4), the addition of shank muscle weight to this equation reduced the standard error from 1.89% to 1.47% (Equation 7).

The other variables used did not contribute much to reducing the standard errors of estimate. Rib-eye area in some cases increased the standard error when it was added (Equations 9 and 10, 14 and 15 and 20 and 21). In the other cases it reduced the standard error very little. Kidney fat weight was useful occasionally but it was also inconsistent. When this variable was added to Equation 5, it increased the standard error by 0.01% (Equation 6). Carcass weight was used often, and with good success, but the bias that this variable might introduce may eventually limit its use.

Based on these results, I feel quite confident that good equations to predict cutability or percent muscle can be developed for commercial use. The equation should include average rib fat thickness and perhaps carcass weight and shank muscle weight.

CONCLUSIONS

A study was made to determine the relationships between certain measurements and carcass cutability. Many variables were investigated but only a few appeared to be suitable for use in predicting yield.

Carcass grade did not adequately describe a carcass with respect to lean content. In fact this study and others showed that there is an inverse relationship between grade and cutability. As grade improved cutability decreased. There is also a substantial variation in yield from carcasses of the same grade. I feel that carcass grade as it is presently used is not adequate and could be improved.

Hot carcass weight was not highly correlated with cutability or percent lean in any of the three groups of cattle studied. It was highly correlated however with weight of lean. In spite of the low correlations with cutability, carcass weight usually reduced the standard errors of prediction equations in which it was used. I feel that good carcasses that are heavier or lighter than the average could be unjustly dealt with. Before carcass weight could be used in an equation with confidence it should be very carefully examined to determine just how it affects these non-typical carcasses.

Rib-eye area was not well correlated with cutability in any of the groups of cattle studied. It was usually strongly related to carcass weight however. In several prediction equations the standard error of estimate was increased when rib-eye area was added to the equation. In a few equations it reduced the error a little.

Overall, I do not feel that I could recommend its use. Each equation would have to be tested to determine the effect of adding or subtracting rib-eye area.

Average rib fat thickness showed a great deal of promise as a reliable predictor of cutability or percent carcass muscle in all three groups of animals. This measurement produced the second smallest standard error in all three groups when predicting cutability by use of a single variable. It also performed very well in combination with other variables. When predicting percent muscle the rib fat measurement was the most useful single predictor variable in the Kinsella steers.

Carcass length showed no significant correlation with either cutability or percent carcass lean. From the results of this experiment there appears to be no reason to use this variable in any prediction equation for carcass yield.

Kidney fat did not provide large correlations with cutability or even with carcass fat weight. It could not be used as a principle variable to predict carcass lean or cutability. The correlations were high enough however to cause a reduction in the standard errors of most predictions when added as one of a number of variables. More work needs to be done to determine the effect of breeding and carcass weight on kidney fat weight. For the present, based on these results, kidney fat can be used in a prediction equation if carefully examined as to how much additional accuracy its inclusion will offer.

Percent retail round closely approximated cutability in all three groups of animals. It was the most accurate single

predictor variable and produced prediction equations for cutability with the lowest standard errors, often less than two percent. This variable was about equal to average rib fat in predicting percent carcass lean. The prediction equations using this joint will probably be limited to research studies because the cost and time involved will probably be too high for commercial operations. Nevertheless this joint can be used to very accurately predict the cutability of the whole carcass, especially if other variables are added to the equation. It could substitute for total carcass dissection or total carcass butchering for research projects not involving exact carcass studies.

Shank dissection provided very useful data for prediction equations. When the weight of the shank muscle was added to other variables the standard errors of these equations were reduced substantially. From this rather limited testing it appears that the shank muscle weight could be very useful in commercial prediction equations, especially since it is an inexpensive joint and easy to dissect. Shank bone weight proved a very reliable predictor of percent carcass bone, should this estimate ever be required. Shank muscle to bone ratio was not correlated with any useful variables and was thus not useful in prediction equations.

Cutability was predicted using a number of equations. The most accurate had standard errors of 1.5 to 2.0 percent. It appeared that it would be possible to predict cutability with enough accuracy to be useful to both industry and animal research. Some doubt was cast, however, as to whether cutability is the best end point for industry and research. This research showed that percent carcass

muscle was more accurately predicted than cutability. It appeared that it would be more meaningful to industry if prediction equations were based on percent muscle rather than cutability. This would then eliminate any need for packers or those developing the equations, to determine the degree of fat trim required for retail cuts. This could be left up to the retailor to set as his customers dictated.

The prediction equations apparently offering the most potential for commercial use should include average rib fat thickness, shank muscle weight and any of carcass weight, loin eye area or kidney fat weight that proved to reduce the standard error.

Based on the results of this research I feel quite confident that the above variables could be successfully arranged to produce a prediction equation that would meet the needs of industry or science and would provide a suitable method evaluating the worth of a carcass. This equation should probably be updated frequently to account for the changing beef type. Whatever the form it should be a fairer system than our present method.

BIBLIOGRAPHY

Abraham, H. C., Z. L. Carpenter, G. T. King and O. D. Butler. 1967. Determinants of beef carcass cutability. J. Animal Sci. 26:892 (abstr.).

Abraham, H. C., Z. L. Carpenter, G. T. King and O. D. Butler. 1968. Relationships of carcass weight, conformation and carcass measurements and their use in predicting beef carcass cutability. J. Animal Sci. 27:604-610.

Adam, J. L. and W. C. Smith. 1964. The use of specific gravity and its reciprocal in predicting the carcass composition of pigs slaughtered at three weights. Animal Prod. 6:97-105.

Barton, R. A. and A. H. Kirton. 1956. Determination of fat in mutton carcasses by measurement of specific gravity. Nature, 178:920.

Bennink, M. R., G. M. Ward, J. E. Johnson and D. A. Cramer. 1968. Potassium content of carcass components and internal organs of cattle as determined by K^{40} and atomic absorption spectrometry. J. Animal Sci. 27:600-603.

Berg, R. T. 1969. Growth and carcass composition of heifers, steers and bulls. 48th Annual Feeders' Day Report, Department of Animal Science, University of Alberta, Edmonton. pp. 24-28.

Berg, R. T. 1970. Carcass merit in beef production. Department of Animal Science, University of Alberta, Edmonton. Paper prepared for Cattleman's Short Course, Hanna.

Berg, R. T. and R. M. Butterfield. 1966. Muscle:bone ratio and fat percentage as measures of beef carcass composition. An. Prod. 8:1-11.

Berg, R. T. and R. M. Butterfield. 1968. Growth patterns of bovine muscle, fat and bone. J. Animal Sci. 27:611-619.

Berg, R. T. and L. W. McElroy. 1968. The University of Alberta beef breeding project. 47th Annual Feeders' Day Report. Department of Animal Science, University of Alberta, Edmonton. pp. 23-28.

Berg, R. T. and H. M. Mukhoty. 1970. Lean distribution in carcasses from bulls, steers and heifers of various breeds. 49th Annual Feeders' Day Report, Department of Animal Science, University of Alberta, Edmonton. pp. 40-41.

Birkett, R. J., D. L. Good and D. L. Mackintosh. 1965. Relationship of various linear measurements and percent yield of trimmed cuts of beef carcasses. J. Animal Sci. 24:16-20.

Brackelsberg, P. O. and R. L. Willham. 1968. Relationships among some common live and carcass measurements and beef carcass composition. J. Animal Sci. 27:53-57.

Branaman, G. A., A. M. Pearson, W. T. Magee, R. M. Griswold and G. A. Brown. 1962. Comparison of the cutability and eatability of beef- and dairy-type cattle. J. Animal Sci. 21:321-326.

Bray, R. W. 1963. Quantitative measures of carcass composition and qualitative evaluations. J. Animal Sci. 22:548-554.

Brown, C. J., J. C. Hiller and J. A. Whatley. 1951. Specific gravity as a measurement of fat content of the pork carcass. J. Animal Sci. 10:97-103.

Brungardt, V. H. and R. W. Bray. 1963. Estimate of retail yield of the four major cuts in the beef carcass. J. Animal Sci. 22:177-182.

Busch, D. A., C. A. Dinkel and J. A. Minyard. 1969. Body measurements, subjective scores and estimates of certain carcass traits as predictors of edible portion in beef cattle. J. Animal Sci. 29:557-566.

Busch, D. A., C. A. Dinkel, D. E. Schafer, H. J. Tuma and B. C. Breidenstein. 1968. Predicting edible portion of beef carcasses from rib-section data. J. Animal Sci. 27:351-354.

Butterfield, R. M. 1965. The relationship of carcass measurements and dissection data to beef carcass composition. Res. Vet. Sci. 6:24-32.

Butterfield, R. M. and R. T. Berg. 1966a. A nutritional effect on relative growth of muscles. Proc. Australian Soc. Animal Prod. 6:298-304.

Butterfield, R. M. and R. T. Berg. 1966b. A classification of bovine muscles, based on their relative growth patterns. Res. Vet. Sci. 7:326-332.

Butterfield, R. M. and N. D. S. May. 1965. The muscles of the ox. University of Queensland Press, Brisbane, Australia.

Butterfield, R. M., W. J. Pryor and R. T. Berg. 1966. A study of carcass growth in calves. Res. Vet. Sci. 7:417-422.

Callow, E. H. 1962. The relationship between the weight of a tissue in a single joint and the total weight of the tissue in a side of beef. Animal Prod. 4:37-46.

Carroll, F. D., M. T. Clegg and D. Kroger. 1964. Carcass characteristics of Holstein and Hereford steers. J. Agri. Sci. 62:1-6.

Carroll, M.A. 1966. Problems in beef carcass evaluation. Proc. 9th International Congress of Animal Prod. T. A. Constable Ltd., Edinburgh. p. 117.

Clark, K. W., M. L. Dudzinski, R. M. Butterfield and D. Bennett. 1964. The muscle, fat, and bone content of Angus steer carcasses as affected by stocking rates. Australian J. Agri. Res. 15:858-867.

Cobb, E. H. and A. Ovejera. 1965. Predicting yield of trimmed retail cuts in beef carcasses. Proc. West. Sec. Am. Soc. Animal Prod. 16: XXX pp. 1-6.

Cole, J. W., L. E. Orme and C. M. Kincaid. 1960. Relation of loin eye area, separable lean of various beef cuts and carcass measurements to total carcass lean in beef. J. Animal Sci. 19:89-100.

Cole, J. W., C. B. Ramsey and R. H. Epley. 1962. Simplified method for predicting pounds of lean in beef carcasses. J. Animal Sci. 21:355-361.

Davis, J. K., R. S. Temple and W. C. McCormick. 1966. A comparison of ultrasonic estimates of rib-eye area and fat thickness in cattle. J. Animal Sci. 25:1087-1090.

Epley, R. J., H. B. Hendrick, W. C. Stringer and D. P. Hutcheson. 1970. Prediction of weight and percent retail cuts of beef using five carcass measurements. J. Animal Sci. 30:872-879.

Field, R. A., J. D. Kemp and W. Y. Varney. 1962. Indices for lamb carcass composition. J. Animal Sci. 21:980 (abstr.).

Fitzhugh, H. A., Jr., F. T. King, F. A. Orts, Z. L. Carpenter and O. D. Butler. 1965. Method of predicting the weight of boneless roasts and steak meat from easily obtained beef carcass measurements. J. Animal Sci. 24:168-172.

Fredeen, H. T., R. T. Berg, J. P. Bowland and H. Doornenbal. 1964. Prediction of yield and value of hog carcasses. Canadian J. Animal Sci. 44:334-346.

Goll, D. E., E. A. Kline and L. N. Hazel. 1961a. Influence of beef carcass grade and weight on yield of wholesale cuts and carcass measurements. J. Animal Sci. 20:260-263.

Goll, D. E., L. N. Hazel and E. A. Kline. 1961b. Relationship between some beef carcass measurements and yields of wholesale cuts. J. Animal Sci. 20:264-267.

Gottsch, A. H., R. A. Merkel and D. L. Mackintosh. 1961. Relationship of muscle, fat, bone and some physical measurements to beef carcass cutability. J. Animal Sci. 20:917 (abstr.).

Hammond, J. 1932. Growth and the development of mutton qualities of sheep. Oliver and Boyd, Edinburgh and London.

Hankins, O. G. 1947. Estimation of the composition of lamb carcasses and cuts. U.S.D.A. Tech. Bull. 944.

Hankins, O. G. and P. E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. U.S.D.A. Tech. Bull. 926.

Harrington, G. and J. W. B. King. 1963. A note on the prediction of muscular tissue weight in the sides of beef. Animal Prod. 5:327-328.

Henderson, D. W., D. E. Goll and E. A. Kline. 1966. Relationships of muscling and finish measurements from three different groups of beef carcasses with carcass yield. J. Animal Sci. 25:323-328.

Hedrick, H. B., W. E. Meyer, M. A. Alexander, S. E. Zobrisky and H. D. Naumann. 1962. Estimation of rib-eye area and fat thickness of beef cattle with ultrasonics. J. Animal Sci. 21:362-365.

Isler, G. A. and L. A. Swiger. 1968. Ultrasonic prediction of lean cut percent in swine. J. Animal Sci. 27:377-382.

Jobblin, A. D. H. 1966a. The estimation of carcass composition in bacon-weight pigs. ii. The use of specific gravity. N.Z. J. Agri. Res. 9:227-240.

Jobblin, A. D. H. 1966b. The estimation of carcass composition in bacon-weight pigs. iii. The use of butcher's dissections and full dissections of sample joints. N.Z. J. Agri. Res. 9:241-251.

Johnston, D. D., W. E. Tyler, C. E. Murphey, E. F. Kimbrell, D. F. Manns, C. L. Strong, Z. L. Carpenter and G. T. King. 1967. Estimating yields of retail cuts from lamb carcasses. J. Animal Sci. 26:896 (abstr.).

Judge, M. D., T. G. Martin and J. B. Outhouse. 1966. Prediction of carcass composition of ewe and wether lambs from carcass weights and measurements. J. Animal Sci. 25:92-95.

Kauffman, R. G. 1965. Some aspects of physiological growth of meat animals. Proc. 18th Annual Reciprocal Meat Conference, National Livestock and Meat Board, Chicago, Ill. pp. 220-234.

Kennick, W. H., D. C. England and A. F. Anglemier. 1963. Method of estimating percent of protein and fat in the boneless portion of steer carcasses. J. Animal Sci. 22:989-992.

Kirton, A. H., A. M. Pearson, E. C. Anderson and R. L. Schuch. 1960. The use of naturally occurring K^{40} to determine the carcass composition of live sheep. J. Animal Sci. 19:1237 (abstr.).

Kraybill, H. F., H. L. Bitter and O. G. Hankins. 1952. Body composition of cattle. ii. Determination of fat and water content from measurement of body specific gravity. J. App. Phys. 4:575-583.

Kropf, D. H. and R. L. Graf. 1959 . The effect of carcass grade, weight and classification upon boneless beef yield. J. Animal Sci. 18:95-103.

Kulwich, R., L. Feinstein and C. Golumbic. 1960a. Beta radioactivity of the ash in relation to the composition of ham. J. Animal Sci. 19:119-126.

Kulwich, R., L. Feinstein, C. Golumbic, R. L. Hiner, W. R. Seymour and W. R. Kauffman. 1960b. Relationship of gamma ray measurements to the lean content of hams. J. Animal Sci. 19:1238-1239 (abstr.).

Kulwich, R., L. Feinstein, C. Golumbic, W. R. Seymour, W. R. Kauffman and R. L. Hiner. 1961. Relation of gamma ray emmission to the lean content of beef rounds. Food Technol. 15:411-414.

Latham, S. D., W. G. Moody and J. D. Kemp. 1966. Techniques for estimating lamb carcass composition. J. Animal Sci. 25: 492-496.

Ledger, H. P. 1959. A possible explanation for part of the difference in heat tolerance exhibited by Box taurus and Box indicus cattle. Nature, 184:1405-1406.

Lohman, T. G., and H. W. Norton. 1968. Distribution of potassium in steers by K^{40} measurement. J. Animal Sci. 27:1266-1272.

McMeekan, C. P. 1941. Growth and development in the pig, with special reference to carcass quality characters. J. Agri. Sci. 31:1-49.

McReynolds, W. E. and V. H. Arthaud. 1970. Ultrasonic application for estimating fat thickness of beef cattle. J. Animal Sci. 30:186-190.

Meyer , T. O. and M. E. Ensminger. 1952. Consumer preference and knowledge of quality in retail beef cuts. Wash. Agri. Exp. Sta. Cir. 168.

Murphey, C. E., D. K. Hallett, W. E. Tyler and J. C. Pierce, Jr. 1960. Estimating yields of retail cuts from beef carcasses. J. Animal Sci. 19:1240 (abstr.).

Murphey, C. E., D. K. Hallett, K. E. Hoke and B. C. Breidenstein. 1963. Factors affecting yields of cuts from beef carcasses. J. Animal Sci. 22:828-829 (abstr.).

Orme, L. E., J. W. Cole, C. M. Kincaid and R. J. Cooper. 1960. Predicting total carcass lean in mature beef from weights of certain entire muscles. J. Animal Sci. 19:726-734.

Palsson, H. 1939. Meat qualities in the sheep with special reference to Scottish breeds and crosses. Part 1. J. Agri. Sci. 29:544-626.

Ramsey, C. B., J. W. Cole and C. S. Hobbs. 1962. Relation of beef carcass grades, proposed yield grades and fat thickness to separable lean, fat and bone. J. Animal Sci. 21: 193-195.

Stant, E. G., Jr., T. G. Martin and W. V. Kessler. 1969. Potassium content of the porcine body and carcass at 23, 46, 68 and 91 kilograms live weight. J. Animal Sci. 29:547-556.

Stouffer, J. R. 1963. Relationship of ultrasonic measurements and x-rays to body composition. Annals of the New York Academy of Sci. 110:31.

Stouffer, J. R. and G. H. Wellington. 1960. Ultrasonics for evaluation of live animal and carcass composition. Proc. of the 12th Res. Conf., American Meat Institute Foundation, 81.

Stouffer, J. R., M. V. Wallentine, G. H. Wellington and A. Diekmann 1961. Development and application of ultrasonic methods for measuring fat thickness and rib-eye area in cattle and hogs. J. Animal Sci. 20:759-767.

Snedecor, G. W. 1948. Statistical Methods. 4th ed. Iowa State College Press, Ames, Iowa.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York.

Stringer, W. C., C. L. Cramer, K. O. Zoellner, V. J. Rhodes and H. D. Naumann. 1963. Retail yield estimates of market steers and carcasses. J. Animal Sci. 22:829 (abstr.).

Temple, R. S., H. H. Stonaker, D. Howary, G. Posakony and H. M. Hazaleus. 1956. Ultrasonic and conductivity methods for estimating fat thickness in live cattle. Proc. West. Sec. Am. Soc. Animal Prod. 7: 477.

Thornton, J. W. and R. L. Hiner. 1965. Volume of beef round related to carcass composition. J. Animal Sci. 24:301-304.

Tulloh, N. M. 1964. Comparative studies of beef cattle. Australian J. Agri. Res. 15:333-345.

Ward, G. M., J. E. Johnson and T. R. Tyler. 1967. Relationship of potassium measured as K^{40} to the moisture and fat of ground beef. J. Animal Sci. 26:298-301.

Woodward, R. R., F. J. Rice, J. R. Quesenberry, R. L. Hiner, R. T. Clark and F. S. Willson. 1960. Relationships between measures of performance, body form and carcass quality of beef cattle. Mont. Exp. Sta. Bull. 550.

APPENDIX TABLE 1

Simple correlations among carcass measurements and shank dissection variables for the ABCPA steers+

	Variables++									
	1-G	2-CW	3-REA	4-AF	5-L	6-KF	7-%RR	18-Y	8-SM	9-SB
					N=165					
2	0.34									
3	0.07	0.60								
4	0.00	0.40	0.06							
5	0.27	0.82	0.51	0.12						
6	0.22	0.47	0.20	0.22	0.39					
7	0.46	0.14	0.21	-0.10	0.03	-0.00				
18	0.40	0.10	0.18	-0.32	-0.06	-0.12	0.81			
					N=38					
8	0.56	0.86	0.82	-0.15	0.70	0.37	0.17	0.34		
9	0.66	0.85	0.73	-0.25	0.75	0.26	0.02	0.31	0.86	
10*	-0.37	-0.32	-0.13	0.20	-0.39	0.02	0.26	-0.06	-0.11	-0.58

\+ Number of observations is 165 for carcass data and 38 for shank and carcass data

Significance levels for 163 degrees of freedom: 5% = 0.15
(Significance levels from Snedecor, 1946) 1% = 0.20

Significance levels for 36 degrees of freedom: 5% = 0.32
(Significance levels from Snedecor, 1946) 1% = 0.41

* Shank muscle to bone ratio

++ For description of variables, see Table 2

APPENDIX TABLE 2

Simple correlation among carcass measurement variables for 38 ABCPA heifers

	Variables						
	1-G	2-CW	3-REA	4-AF	5-L	6-KF	7-%RR
2	-0.29						
3	-0.46	0.68					
4	-0.28	0.73	0.41				
5	-0.05	0.90	0.50	0.60			
6	0.09	0.32	-0.02	0.23	0.41		
7	-0.05	-0.22	-0.13	-0.39	-0.21	-0.25	
18+	-0.03	0.00	0.19	-0.40	0.04	-0.32	0.78

\+ Cutability

Significance levels for 36 degrees of freedom: 5% = 0.32
(Significance levels from Snedecor, 1946) 1% = 0.41

APPENDIX TABLE 3

Simple correlations among carcass measurement and total dissection variables for nine ABCPA steers

	Variables															
	2-CW	3-REA	4-AF	5-L	6-KF	7-%HRR	8-SM	9-SB	10-SM/SB	11-%M	12-%B	13-%F	14-M	15-F	16-B	17-M/B
3	0.60															
4	-0.08	-0.08														
5	0.75	0.39	-0.33													
6	0.17	0.14	0.53	-0.15												
7	0.08	0.35	-0.20	-0.13	-0.41											
8	0.73	0.76	-0.21	0.25	0.15	0.44										
9	0.69	0.64	-0.38	0.67	-0.48	0.29	0.58									
10	0.11	0.21	0.15	-0.40	0.70	0.16	0.51	-0.40								
11	0.43	0.49	-0.52	0.09	-0.16	0.53	0.80	0.47	0.41							
12	0.29	0.43	-0.55	0.60	-0.71	0.26	0.16	0.81	-0.66	0.33						
13	-0.48	-0.55	0.63	-0.28	0.34	-0.54	-0.75	-0.66	-0.15	-0.96	-0.59					
14	0.92	0.67	-0.26	0.58	-0.01	0.38	0.90	0.76	0.21	0.72	0.37	-0.75				
15	0.24	-0.16	0.54	0.33	0.56	-0.58	-0.32	-0.24	-0.10	-0.70	-0.36	0.69	-0.14			
16	0.79	0.65	-0.34	0.82	-0.36	0.26	0.55	0.95	-0.37	0.43	0.80	-0.63	0.80	-0.06		
17	-0.03	-0.13	0.23	-0.55	0.62	0.05	0.33	-0.53	0.92	0.30	-0.80	-0.00	0.06	-0.08	-0.55	
18+	0.19	0.28	-0.38	-0.02	-0.57	0.93	0.47	0.48	-0.01	0.60	0.41	-0.65	0.50	-0.60	0.42	-0.06

\+ Cutability

Significance levels for seven degrees of freedom: 5% = 0.67
1% = 0.79

(Significance levels from Snedecor, 1946)

APPENDIX TABLE 4

Simple correlations between carcass measurement and total dissection variables for 40 Kinsella steers

	1-G	2-CW	3-REA	4-AF	6-KF	7-%RR	8-SM	9-SB	10-SM/SB	11-%M	12-%B	13-%F	14-M	15-F	16-B	17-M/B
2	0.18															
3	0.28	0.36														
4	-0.52	0.16	-0.38													
6	-0.12	0.35	0.47	-0.07												
7	0.38	-0.06	0.42	-0.79	0.12											
8	0.39	0.52	0.46	-0.46	0.04	0.54										
9	0.59	0.63	0.40	-0.34	0.12	0.29	0.75									
10	-0.21	-0.11	0.12	-0.23	-0.11	0.42	0.43	-0.27								
11	0.57	0.01	0.51	-0.88	0.06	0.86	0.68	0.49	0.35							
12	0.65	0.17	0.36	-0.53	-0.00	0.46	0.62	0.75	-0.11	0.67						
13	-0.65	-0.05	-0.47	0.84	-0.00	-0.79	-0.71	-0.60	-0.24	-0.98	-0.80					
14	0.53	0.61	0.58	-0.57	0.24	0.65	0.86	0.77	0.22	0.78	0.63	-0.78				
15	-0.58	0.30	-0.33	0.86	0.09	-0.75	-0.48	-0.36	-0.24	-0.92	-0.72	0.94	-0.52			
16	0.58	0.63	0.43	-0.30	0.14	0.31	0.75	0.90	-0.13	0.50	0.86	-0.62	0.80	-0.38		
17	-0.27	-0.22	0.09	-0.26	0.09	0.36	-0.07	-0.48	0.56	0.21	-0.58	-0.01	0.03	-0.06	-0.58	
18+	0.57	-0.06	0.33	-0.81	-0.07	0.88	0.62	0.43	0.32	0.90	0.63	-0.89	0.68	-0.86	0.45	0.15

\+ Cutability

Significance levels for 38 degrees of freedom: 5% = 0.31
1% = 0.40

(Significance levels from Snedecor, 1946)

APPENDIX TABLE 5

Multiple linear regression equations to predict cutability (Y) for 165 ABCPA steers

Equation Number	Dependent Variable	Variables										a	R	SE
		G	CW	REA	AF	L	KF	%RR	SM	SB	SM/SB			
1	Y	2.238										70.26	0.41	2.60
2	Y		0.012									70.35	0.10	2.83
3	Y			0.070								68.68	0.18	2.80
4	Y				-0.214							77.27	0.32	2.70
5	Y		0.031		-0.288							71.08	0.40	2.61
6	Y		0.026	0.026	-0.278							70.52	0.41	2.62
7	Y						-0.199					74.23	0.12	2.83
8	Y				-0.206		-0.088					77.60	0.32	2.70
9	Y					0.038						68.72	0.06	2.84
10	Y		0.042		-0.283		-0.333					70.23	0.44	2.57
11	Y							0.955				3.52	0.81	1.68
12	Y		0.019		-0.185		-0.218	0.891				8.36	0.85	1.49
13	Y								0.0052			64.89	0.34	2.73
14	Y									0.0056		67.22	0.31	2.75
15	Y										-1.470	74.84	0.06	2.89
16	Y				-0.482				0.0039			75.36	0.63	2.28
17	Y				-0.527						1.256	79.91	0.58	2.39
18	Y			0.038	-0.470				0.0026			74.62	0.63	2.31
19	Y		-0.047		-0.397				0.0095			76.75	0.66	2.25
20	Y		-0.091						0.0156			71.18	0.53	2.50
21	Y			0.040	-0.482				0.0027		1.778	71.87	0.64	2.33
22	Y		-0.054	0.074	-0.361				0.0079			75.52	0.66	2.26

Equations number 1-12 have a standard deviation of 2.84 for Y with 165 observations
Equations number 13-22 have a standard deviation of 2.86 for Y with 38 observations

APPENDIX TABLE 6

A comparison of multiple linear regression equations predicting cutability (Y) or percent muscle (%M) for 9 ABCPA steers

Equation Number	Dependent Variable	Variables									a	R	SE
		CW	REA	AF	L	KF	SM	SB	SM/SB	%RR			
1	Y	0.053									60.40	0.19	2.85
2	%M	0.078									43.31	0.43	1.78
3	Y		0.173								61.80	0.28	2.79
4	%M		0.210								48.19	0.49	1.71
5	Y			-0.577							81.42	0.38	2.68
6	%M			-0.532							69.03	0.52	1.67
7	Y	0.045		-0.557							71.51	0.42	2.85
8	%M	0.072		-0.502							53.31	0.65	1.61
9	Y	0.007	0.146	-0.545							71.12	0.46	3.06
10	%M	0.034	0.146	-0.490							52.92	0.70	1.65
11	Y				0.014						70.06	0.02	2.90
12	%M				0.048						54.61	0.09	1.96
13	Y					-2.579					83.17	0.58	2.38
14	%M					-0.473					62.11	0.16	1.94
15	Y			-0.166		-2.318					84.83	0.58	2.55
16	%M			-0.620		0.499					68.30	0.54	1.78
17	Y	0.081		-0.063		-2.711					67.70	0.65	2.62
18	%M	0.069		-0.531		0.160					53.54	0.65	1.76
19	Y									1.154	-11.07	0.93	1.04
20	%M									0.443	28.22	0.53	1.66
21	Y	0.043		-0.144		-0.971				1.005	-2.79	0.98	0.85
22	%M	0.053		-0.566		0.916				0.437	22.90	0.80	1.55

Standard deviation of cutability (Y) = 2.72
Standard deviation of percent muscle (%M) = 1.84

continued

APPENDIX TABLE 6

A comparison of multiple linear regression equations predicting cutability (Y) or percent muscle (%M) for 9 ABCPA steers

Equation Number	Dependent Variable	Variables									a	RE	SE
		CW	REA	AF	L	KF	SM	SB	SM/SB	%RR			
23	Y						0.0113				56.52	0.47	2.56
24	%M						0.0131				42.54	0.81	1.16
25	Y							0.0194			55.41	0.48	2.55
26	%M							0.0127			49.39	0.47	1.74
27	Y								-0.298		72.09	0.01	2.90
28	%M								6.701		49.28	0.41	1.79
29	Y			-0.446			0.0098				68.12	0.55	2.62
30	%M			-0.374			0.0118				50.60	0.88	1.00
31	Y			-0.588					1.154		79.76	0.38	2.90
32	%M			-0.611					8.201		57.26	0.72	1.47
33	Y		-0.087	-0.428			0.0124				67.30	0.56	2.85
34	%M		-0.093	-0.356			0.0146				51.85	0.89	1.04
35	Y	-0.076		-0.411			0.0149				75.01	0.58	2.79
36	%M	-0.055		-0.349			0.0154				56.94	0.90	0.99
37	Y	-0.089					0.0171				67.79	0.52	2.68
38	%M	-0.065					0.0173				50.80	0.84	1.15
39	Y		-0.200	-0.255			0.0207		-8.742		73.61	0.62	3.01
40	%M		-0.075	-0.384			0.0132		1.439		50.82	0.90	1.15
41	Y	-0.074	-0.071	-0.398			0.0168				75.65	0.59	3.11
42	%M	-0.051	-0.082	-0.334			0.0176				57.68	0.91	1.06

Standard deviation of cutability (Y) = 2.72
Standard deviation of percent muscle (%M) = 1.84

APPENDIX TABLE 7

Multiple linear regression equations to predict bone, fat and weight of muscle for 9 ABCPA steers

Equation Number	Dependent Variable	Variables						a	R	SE	Standard Deviation of Dependent Variables
		CW	REA	AF	KF	SM	SB				
1	%F			0.836				13.53	0.63	2.00	2.40
2	%F				1.365			21.63	0.34	2.41	2.40
3	%F			0.822	0.077			13.42	0.63	2.16	2.40
4	%F	-0.104		0.792				36.36	0.76	1.80	2.40
5	%F	-0.112		0.678	0.624			37.23	0.77	1.93	2.40
6	%F		-0.282	0.781				30.32	0.80	1.65	2.40
7	%B						0.0074	6.21	0.81	0.38	0.62
8	%B	0.018						8.62	0.29	0.63	0.62
9	%B			-0.187				15.55	0.55	0.55	0.62
10	%B	-0.032					0.0106	10.24	0.89	0.32	0.62
11	%B	-0.028		-0.065			0.0095	11.36	0.91	0.33	0.62
12	%B			-0.097			0.0064	8.66	0.85	0.37	0.62
13	B						0.0154	-0.23	0.95	0.36	1.10
14	M	0.400						-25.75	0.92	1.84	4.35
15	M		0.678					21.29	0.67	3.46	4.35
16	M			-0.639				70.21	0.26	4.48	4.35
17	M					0.0345		13.30	0.90	2.05	4.35
18	M	0.246				0.0186		-17.70	0.98	1.10	4.35
19	M	0.250	-0.095			0.0211		-16.53	0.98	1.16	4.35
20	M	0.258	-0.074	-0.291		0.0190		-11.66	0.98	1.08	4.35

APPENDIX TABLE 8

Multiple linear regression equations to predict cutability (Y) for 38 ABCPA heifers

Equation Number	Dependent Variable	Variables							a	R	S.E.
		G	CW	REA	AF	L	KF	%RR			
1	Y	-0.212							72.49	0.03	2.97
2	Y		0.0006						72.13	0.00	2.97
3	Y			0.079					68.21	0.19	2.92
4	Y				-0.335				78.84	0.40	2.73
5	Y		0.075		-0.720				71.99	0.58	2.45
6	Y		0.054	0.089	-0.687				70.78	0.60	2.44
7	Y						-0.819		76.05	0.32	2.81
8	Y				-0.288		-0.620		80.79	0.46	2.67
9	Y					0.022			69.91	0.04	2.97
10	Y		0.090		-0.724		-0.932		73.59	0.68	2.25
11	Y							0.859	9.78	0.78	1.85
12	Y		0.074		-0.451		-0.604	0.717	17.54	0.89	1.39

Standard deviation of cutability (Y) = 2.93

APPENDIX TABLE 9

A comparison of multiple linear regression equations to predict cutability (Y) or percent muscle (%M) for 40 Kinsella steers

Equation Number	Dependent Variable	Variables								a	R	SE
		G	CW	AF	KF	%RR	SM	SB	SM/SB			
1	Y	3.510								70.35	0.57	3.26
2	%M	3.663								53.55	0.57	3.45
3	Y		-0.016							78.99	0.06	3.97
4	%M		0.002							57.60	0.01	4.19
5	Y			0.229						59.62	0.33	3.75
6	%M			0.372						33.49	0.51	3.61
7	Y				-0.594					86.58	0.81	2.33
8	%M				-0.678					71.62	0.88	2.02
9	Y		0.020		-0.603					81.44	0.81	2.34
10	%M		0.044		-0.697					60.42	0.89	1.94
11	Y		0.023	-0.015	-0.613					81.92	0.82	2.37
12	%M		0.025	0.115	-0.642					56.79	0.90	1.89
13	Y					-0.155				76.00	0.07	3.96
14	%M					0.144				57.12	0.06	4.18
15	Y				-0.601	-0.278				88.81	0.82	2.30
16	%M				-0.677	0.005				71.57	0.88	2.04
17	Y		0.038		-0.620	-0.386				79.96	0.83	2.27
18	%M		0.050		-0.703	-0.137				59.90	0.89	1.95
19	Y						1.331			-23.83	0.88	1.90
20	%M						1.384			-44.38	0.86	2.10
21	Y		0.029		-0.245	-0.445	0.978			2.96	0.92	1.62
22	%M		0.043		-0.430	-0.180	0.713			3.74	0.93	1.58

Standard deviation of cutability (Y) = 3.92
Standard deviation of percent muscle (%M) = 4.14

continued

APPENDIX TABLE 9

A comparison of multiple linear regression equations to predict cutability (Y) or percent muscle (%M) for 40 Kinsella steers

Equation Number	Dependent Variable	Variables									a	R	SE
		G	CW	REA	AF	KF	%RR	SM	SB	SM/SB			
23	Y							0.0130			52.94	0.62	3.13
24	%M							0.0151			32.70	0.68	3.07
25	Y								0.0164		58.75	0.43	3.59
26	%M								0.0196		38.99	0.49	3.66
27	Y									9.464	58.49	0.32	3.76
28	%M									10.847	39.49	0.35	3.93
29	Y				-0.491			0.0065			73.53	0.86	2.08
30	%M				-0.553			0.0078			55.91	0.93	1.55
31	Y				-0.570					4.294	78.68	0.82	2.28
32	%M				-0.650					4.955	62.51	0.89	1.93
33	Y			-0.065	-0.506			0.0072			76.98	0.86	2.08
34	%M			0.068	-0.537			0.0071			52.30	0.94	1.53
35	Y		-0.055		-0.415			0.0097			81.17	0.87	2.02
36	%M		-0.031		-0.511			0.0096			60.15	0.93	1.53
37	Y		-0.138					0.0185			79.93	0.76	2.64
38	%M		-0.132					0.0204			58.63	0.79	2.61
39	Y			-0.062	-0.504			0.0069		1.088	75.48	0.86	2.11
40	%M			0.073	-0.535			0.0066		1.679	49.98	0.94	1.54
41	Y		-0.051	-0.028	-0.428			0.0098			82.06	0.87	2.04
42	%M		-0.046	0.102	-0.466			0.0094			56.93	0.94	1.47

Standard deviation of cutability (Y) = 3.92
Standard deviation of percent muscle (%M) = 4.14

APPENDIX TABLE 10

Multiple linear regression equations to predict bone, fat and weight of muscle for 40 Kinsella steers

Equation Number	Dependent Variable	Variables						a	R	SE	Standard Deviation of Dependent Variables
		CW	REA	AF	KF	SM	SB				
1	%F			0.692				15.60	0.84	2.42	4.41
2	%F				-0.013			29.38	0.01	4.46	4.41
3	%F			0.695	0.129			14.56	0.84	2.44	4.41
4	%F	-0.057		0.717				30.06	0.86	2.31	4.41
5	%F	-0.072		0.732	0.334			31.34	0.87	2.26	4.41
6	%F		-0.137	0.636				25.83	0.86	2.34	4.41
7	%B						0.0079	4.37	0.75	0.72	1.08
8	%B	0.013						8.72	0.17	1.07	1.08
9	%B			-0.107				14.19	0.53	0.92	1.08
10	%B	-0.037					0.0111	10.84	0.84	0.59	1.08
11	%B	-0.030		-0.028			0.0101	10.75	0.85	0.59	1.08
12	%B			-0.063			0.0067	6.71	0.81	0.65	1.08
13	B						0.0157	-0.01	0.90	0.81	1.80
14	M	0.282						-0.44	0.61	5.36	6.70
15	M		0.698					27.75	0.59	5.51	6.70
16	M			-0.712				88.21	0.57	5.59	6.70
17	M						0.0311	21.55	0.86	3.41	6.70
18	M	0.105					0.0269	0.92	0.89	3.19	6.70
19	M	0.089	0.249				0.0241	-6.61	0.90	2.97	6.70
20	M	0.206	0.089	-0.535			0.0146	-0.18	0.95	2.12	6.70